THE EXTINCTION CRISIS: FACT OR FICTION?

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The rapid disappearance of species is often referred to as one the world's greatest environmental concerns. The IUCN Red List of Threatened Species, which now includes more than 44,000 animal and plant species, shows that nearly one-quarter of the planet's 5,488 mammals and nearly one-third of the 6,255 amphibians are globally threatened or extinct. Similarly, worrying patterns of threat and decline have been found in other groups, such as birds, reef-building corals, and gymnosperms.

The IUCN Red List is the world's most comprehensive information source on the global conservation status of plant and animal species. Completed and ongoing assessments reveal the level of threat to species (highlighting those facing a high risk of global extinction) whilst also identifying the nature and distribution of major threats. Mapping the distribution of threatened species has identified that the proportion of threatened species differs markedly between groups and that the pattern of threat of one group does not predict the pattern of threat for another. The distribution of threatened species also shows very different patterns compared with depictions of overall diversity.

Numbers of threatened species are increasing across virtually all the major taxonomic groups. There are many drivers of species extinction, all arising either directly or indirectly from human activities. Overwhelmingly, the most common threat is habitat loss, but over-harvesting, incidental mortality, disease, pollution, and climate change are also major influences on the rate of species decline.

The Global Context

Biodiversity loss is one of the world's most pressing crises, with many species declining to critically low levels and with significant numbers going extinct. Biodiversity is essential for mankind because many a number of species, and the ecosystems they form, provide the vast array of goods and services that sustain our lives. However, despite the immense value of biodiversity, over the past 50 years humans have changed ecosystems more rapidly and extensively than in any comparable period of time in human history (Millennium Ecosystem Assessment 2005). This has resulted in a substantial and largely irreversible loss in the diversity of life on earth.

The structure and function of ecosystems have undergone unprecedented changes through the severe impacts of human activities. Land conversion, habitat change, pollution, overexploitation, invasive species and climate change are the direct drivers of threats that are compromising the continued provision of essential ecosystem services.

According to the Millennium Ecosystem Assessment (2005), since 1945, more land has been converted to cropland than in the 18th and 19th centuries combined. In the last several decades, 20% of the world's coral reefs were lost and a further 20% degraded; there has been a similar impact on mangrove areas — a 35% loss in the last several decades. The amount of water in reservoirs has quadrupled, and withdrawals from rivers and lakes have doubled since 1960. Transformations have also occurred across all of the world's biomes: between 1950 and 1990, 5-10% of the area of five biomes had been converted. By 1990, more than two thirds of the area of two biomes and more than half of the area of four others had been converted. (Millennium Ecosystem Assessment 2005).

Increasing human populations have a much greater collective impact on their surroundings particularly when their activities lead to excessive volumes of nutrients entering ecosystems. The flow of reactive nitrogen on the continents has already doubled, and some projections suggest that this may increase further by approximately two-thirds by 2050. Excessive nitrogen flows have severe environmental effects (eutrophication of freshwater and coastal ecosystems, contribution to acid rain, and loss of biodiversity), which contribute to creation of ground-level ozone, destruction of ozone in the stratosphere and global warming, all of which have subsequent adverse effects on human health (Millennium Ecosystem Assessment 2005).

By the end of the century, climate change and its impacts may be the dominant direct drivers of biodiversity loss and changes in ecosystem services globally. The balance of scientific evidence suggests that there will be a significant

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net harmful impact on ecosystem services worldwide, if global mean surface temperatures increase more than 2 °C above pre-industrial levels. This would require CO_2 stabilisation at less than 450 ppm (Millennium Ecosystem Assessment 2005).

The changes that have been made to ecosystems have contributed to substantial net gains in human well-being and economic development. However, often these gains have been achieved at growing costs. Due to the degradation of many ecosystem services, levels of poverty have remained high, and inequities are growing. It is estimated that 1.1 billion people are surviving on an income of less than $1 per day, 70% of whom are in rural areas where they are highly dependent on ecosystem services (Millennium Ecosystem Assessment 2005).

Many people are still unable to access an improved water supply, and more than 2.6 billion lack access to improved sanitation. Water scarcity affects roughly 1-2 billion people worldwide and will continue to worsen, as 5% to possibly 25% of global freshwater use exceeds long-term accessible supplies. On an average, irrigation withdrawals exceed 15-35% of supply rates and are therefore unsustainable (Millennium Ecosystem Assessment 2005).

Most direct drivers of degradation in ecosystem services are growing in intensity in most ecosystems or at best are remaining constant (Millennium Ecosystem Assessment 2005). The result is that we live in an increasingly unsustainable world. This is the context in which we need to consider biodiversity. We are attempting to achieve conservation in a world that is living way beyond its means, and so the rapid loss of biodiversity, especially at the species level, should not surprise us.

The IUCN Red List

It is very important to assess the health of our global ecosystems by providing up-to-date information on the state and trends of wild species. The global tool for doing this is the IUCN Red List of Threatened Species (http://www.iucnredlist.org/).

The IUCN Red List Categories and Criteria (see http://www.iucnredlist.org/documents/redlist_cats_crit_en_v1223290226.pdf) are widely accepted as the most objective and authoritative system available for assessing the global risk of extinction for species (Lamoreux *et al.* 2003; De Grammont and Cuarón 2006; Rodrigues *et al.* 2006; Mace *et al.* 2008). Each species assessed is assigned to one of the following categories, Extinct, Extinct in the Wild, Critically Endangered, Endangered, Vulnerable, Near Threatened, Least Concern and Data Deficient, based on a series of quantitative criteria linked to population trend, population size and structure, and geographic range (Mace *et al.* 2008). Species classified as Vulnerable, Endangered and Critically Endangered are regarded as 'threatened'. The IUCN Red List Criteria can be used to assess the conservation status of any species, apart from microorganisms.

The IUCN Red List is compiled and produced by the IUCN Species Programme based on contributions from a network of thousands of scientific experts around the world in the IUCN Species Survival Commission. Assessments are impartial and peer-reviewed, providing objective data to support national, regional and global conservation priority setting. It is updated regularly and is freely available The Red List is used for many purposes, as summarised in Rodrigues *et al.* (2006) and Vié *et al.* (2009).

One of the IUCN Red List's main purposes is to highlight those species that are facing a high risk of global extinction. However, it is not just a register of names and associated threat categories but it is also a rich, expert-driven compendium of information on species' ecological requirements, geographic distributions (including maps) and threats. The Red List is used to determine what the challenges to nature are, where they are operating and how to combat them.

By assessing the threat status of species, the IUCN Red List has two goals: (i) to identify and document those species most in need of conservation attention if the global extinction rates are to be reduced, and (ii) to provide a global index of the state of change of biodiversity. The first of these goals identifies particular species at risk of extinction; the second goal focuses on using the data in the Red List for multi-species analyses in order to identify and monitor trends in species' status.

The diversity of species on earth is extraordinary. There are an estimated 8-14 million species in existence, 1.8 million of which have been identified and described. The estimates of how much of this diversity is being lost annually are disheartening, with the number of species assessed as threatened increasing every year. By 2008, 44,838 (2.5%) species had been assessed (Fig. 1), of which 869 (2%) have been classified as Extinct or Extinct in the Wild and 16,928 (38%) classified as threatened. Although only a small proportion of the world's species had been assessed by 2008, this sample indicates the serious conservation status of the species looked at so far, how little is still known and how urgent the need is to assess more species.

Despite the limited number of species assessed in relation to the total number of species known, and the significant number of Data Deficient species included in it, the Red List is still the largest dataset of current information

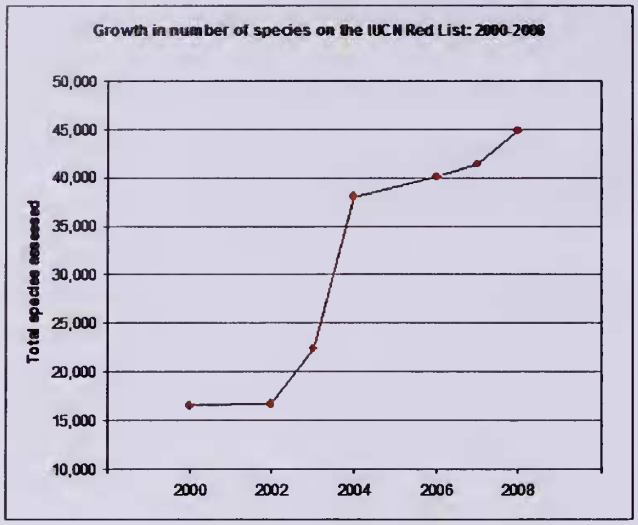

Fig. 1: Number of species appearing on each published IUCN Red List since 2000

on the conservation status of species. Completed and ongoing assessments include the following: BirdLife International bird assessments (updated 5 times since 1988); Global Mammal Assessment (completed in 2008, now being updated); Global Amphibian Assessment (completed in 2004, now being updated); Global Marine Species Assessment (ongoing); Global Freshwater Biodiversity Assessment (ongoing); and Global Reptile Assessment (ongoing). There are various plant and terrestrial invertebrate assessments that have also started and which are gathering speed.

STATUS OF TERRESTRIAL BIODIVERSITY

Comprehensive assessments, covering every species in a taxonomic group, have now been completed for amphibians, birds, mammals, cycads and conifers, warm water reef-forming corals, freshwater crabs and groupers. They are almost complete for sharks and rays, mangroves and sea grasses.

Status of Amphibians

Nearly one-third of the amphibian species (32.4%) are globally threatened or extinct, representing 2,030 species (Fig. 2). Thirty-eight species out of these 2,030 species are considered to be Extinct (EX), one is Extinct in the Wild (EW). Another 2,697 species are not considered to be threatened at present, being classified in the IUCN Categories of Near Threatened (NT) or Least Concern (LC), while sufficient information was not available to assess the status of an additional 1,533 species (Data Deficient (DD). It is predicted that a large proportion of these Data Deficient species are likely to be globally threatened.

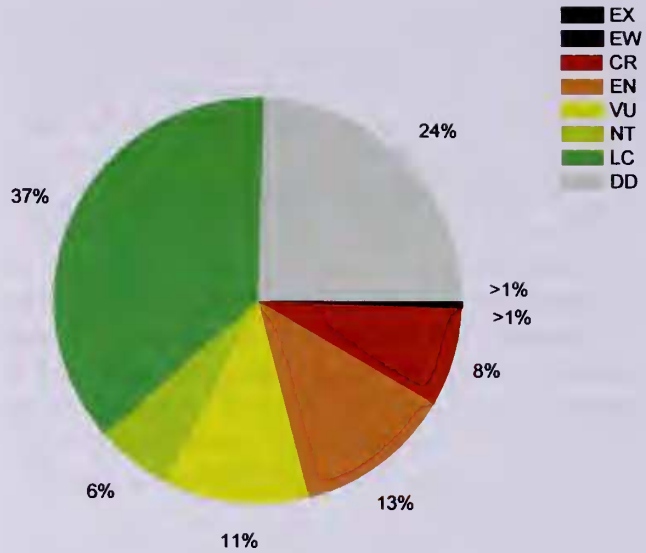

Fig. 2: The status of Amphibians by IUCN Red List categories EX = Extinct; EW = Extinct in the Wild; CR = Critically Endangered; EN = Endangered; VU = Vulnerable; NT = Near Threatened; LC = Least Concern; DD = Data Deficient

Status of birds

Birds are the best known taxonomic group on the IUCN Red List. Since 1988, there have been 5 comprehensive assessments of birds, with the most recent assessment, of all 9,990 known species, being completed in 2008. Less than 1% of bird species on the 2008 IUCN Red List have insufficient information available to be able to assess them beyond Data Deficient.

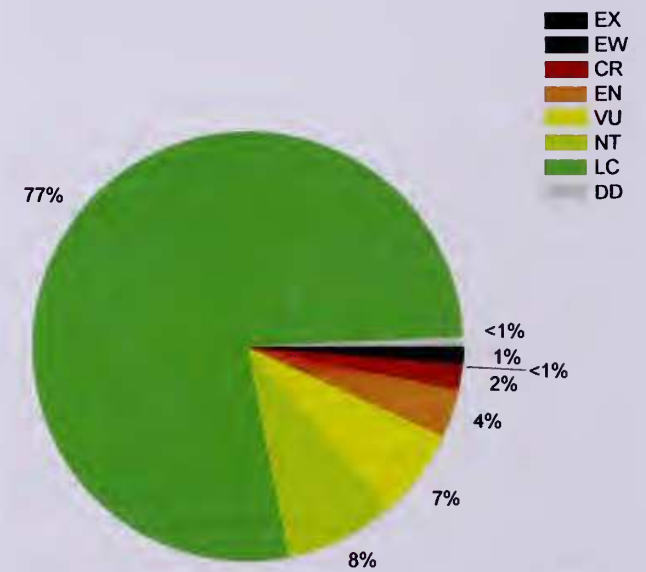

Fig. 3: The status of birds by IUCN Red List categories EX = Extinct; EW = Extinct in the Wild; CR = Critically Endangered; EN = Endangered; VU = Vulnerable; NT = Near Threatened; LC = Least Concern; DD = Data Deficient

It is clear, however, that being well-studied does not provide immunity from decline and high extinction risk. More than 1 in 8 bird species (13.6%) are globally threatened or extinct, representing 1,360 species (Fig. 3). Of these, 134 species (1%) are extinct, 4 species no longer occur in the wild, and a further 15 are Critically Endangered species flagged as 'possibly extinct', making a total of 153 bird extinctions since the year 1500.

Although 8,564 bird species (85.7%) are currently not considered threatened, 835 of these (8.4% of all known birds) are Near Threatened; the remaining 7,729 species are Least Concern.

Status of mammals

The mammal data on the 2008 IUCN Red List include 5,488 species, 412 subspecies and 21 subpopulations. The primary focus is, however, at the species level. This is the second time that all mammals have been assessed, the first being in 1996 (Baillie and Groombridge 1996).

Of the 5,487 mammal species assessed, nearly one-quarter of species (22.2%) are globally threatened or extinct, representing 1,219 species (Schipper *et al.* 2008) (Fig. 4). Seventy-six of the 1,219 species are considered to be Extinct (EX), and 2 Extinct in the Wild (EW). Another 3,432 species are not considered to be threatened at present, being classified in the IUCN Red List categories of NT or LC, while there was insufficient information available to assess the status of an additional 836 species (DD).

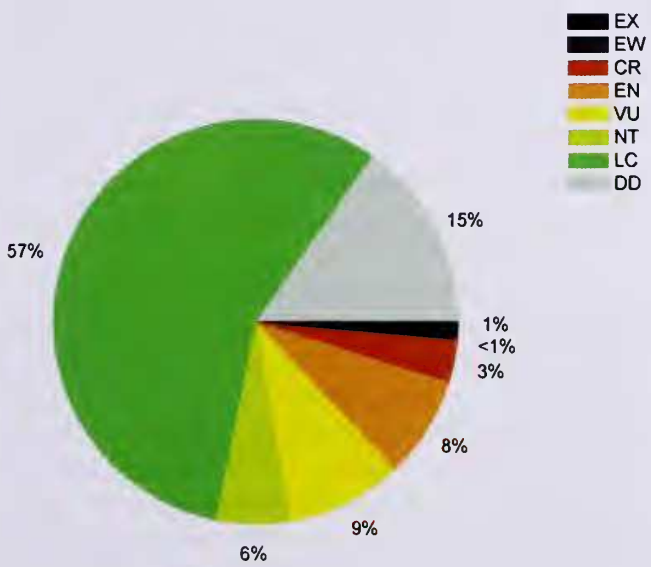

Fig. 4: The status of mammals by IUCN Red List categories EX = Extinct; EW = Extinct in the Wild; CR = Critically Endangered; EN = Endangered; VU = Vulnerable; NT = Near Threatened; LC = Least Concern; DD = Data Deficient

STATUS OF FRESHWATER BIODIVERSITY

IUCN is working with a number of partner organisations to fill the information gap on freshwater species. This is being accomplished by conducting assessments of all known species within the following priority groups: freshwater fishes, freshwater molluscs, dragonflies and damselflies, freshwater crabs and selected aquatic plant families. With the exception of the crabs, none of these assessments is yet complete globally.

There have, however, been some comprehensive regional assessments, in which every described species from a taxonomic group within a region has been assessed. This has enabled the identification of river or lake basins containing the highest levels of species richness, threatened species, restricted range species, migratory species and/or species important to the livelihoods of local communities.

The freshwater assessments completed for eastern and southern Africa have identified lakes Malawi and Victoria, the lower Malagarasi drainage (Tanzania), the Kilombero Valley (Tanzania) and the Southwestern Cape (South Africa) as containing some of the highest numbers of threatened species (Fig. 5).

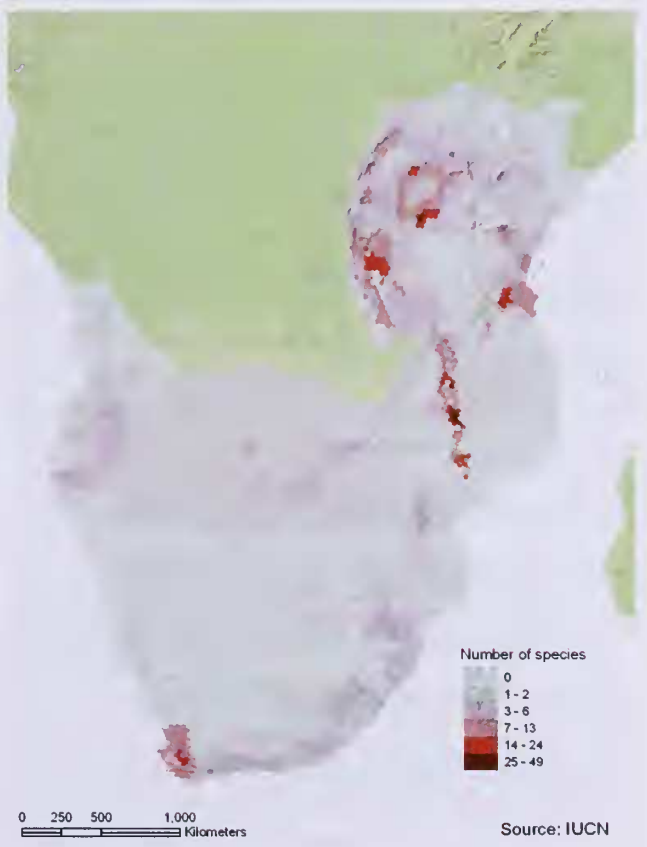

Fig. 5: Distribution patterns of regionally threatened species for freshwater fishes, molluscs, odonates (dragonflies and damselflies) and crabs across eastern and southern Africa

Freshwater biodiversity is being threatened by a number of key impacts, including overexploitation, water pollution, river flow modification (including water abstraction), destruction or degradation of habitats, and invasion by invasive alien species (Millennium Ecosystem Assessment 2005; Dudgeon *et al.* 2006). Compounding these threats are the predicted global impacts of climate change leading to temperature changes and shifts in precipitation and runoff patterns (Dudgeon *et al.* 2006).

Using freshwater fishes as an example, being one of the most widely assessed of the freshwater species groups, the level, nature and distribution of major threats can be identified. Of the regions assessed so far, the Mediterranean and Malagasy endemic freshwater fish are shown to have the highest proportions of globally threatened species, with more than 50% of species threatened in each case, and southern Africa to have the lowest proportion, with 17% of species threatened (Fig. 6).

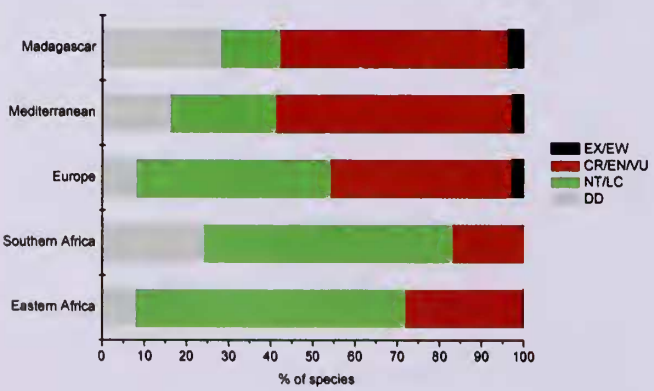

Fig. 6: Proportions of freshwater fish species by threat category in each of the regions assessed comprehensively. Only species endemic to each region are included

THE STATUS OF MARINE BIODIVERSITY

In recent years, there has been growing concern in the scientific community that a broad range of marine species could be under threat of extinction and that marine biodiversity is experiencing potentially irreversible loss due to overfishing, climate change, invasive species and coastal development (Roberts and Hawkins 1999; Dulvy *et al.* 2003).

In 2006, IUCN, Conservation International and Old Dominion University initiated an ambitious project (the Global Marine Species Assessment) to complete IUCN Red List assessments for a greatly expanded number of marine species. It is planned to complete Red List assessments for over 20,000 marine species by 2012. Much progress has already been made, and approximately 1,500 marine species have been added to the 2008 Red List. IUCN has now assessed all of the world's known species of sharks and relatives, groupers, reef-building

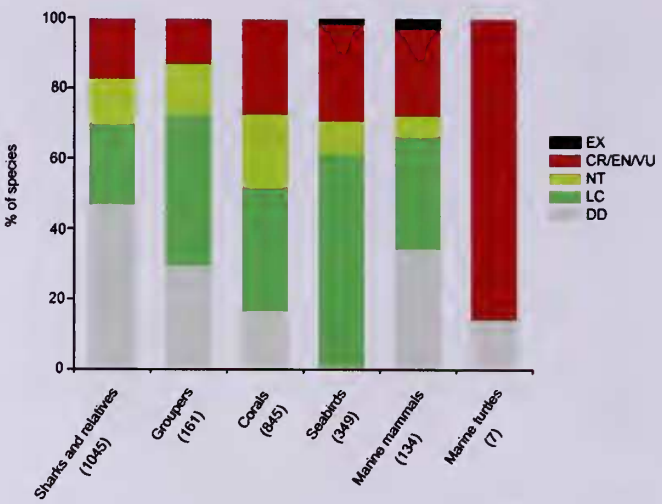

Fig. 7: Summary of 2008 Red List categories for completed clades of marine species
Number of species assessed in each group in parentheses
[black=EX; red=CR/EN/VU; yellow=NT; green=LC; grey=DD]

corals, (seabirds, marine mammals and marine turtles). Work on the sharks and rays is nearing completion. The overall results of these assessments (including the preliminary results for sharks and rays) are shown in Fig. 7.

The threat status of the different taxonomic groups varies quite widely. Overfishing and incidental mortality are particular common threats in the sea. However, with the reef-building corals, the situation is significantly different, as described below.

The world's known 845 species of reef-building zooxanthellate corals (Order Scleractinia plus the families Helioporidae, Tubiporidae and Milleporidae) were assessed for the first time (Carpenter *et al.* 2008). These reef-building corals provide the essential habitat for many species of fish and invertebrates, making them the most biologically diverse ecosystems in the ocean. More than one-quarter of these corals (27%) have been listed in threatened categories, representing an elevated risk of extinction. Over 20% of species are listed as Near Threatened and are expected to join a threatened category in the near future.

The primary threat to these reef-building corals is the increased frequency and duration of bleaching and disease events that have been linked to the increase in sea temperatures, a symptom of global climate change (Carpenter *et al.* 2008). These impacts are further compounded by anthropogenic threats, including coastal development, coral extraction, sedimentation and pollution. Another further threat to corals is ocean acidification as a result of increasing levels of atmospheric carbon dioxide. This is reducing ocean carbonate ion concentrations and the ability of corals to build skeletons.

Globally, the Indo-Malay-Philippine Archipelago or the 'Coral Triangle' has by far the highest number of coral species,

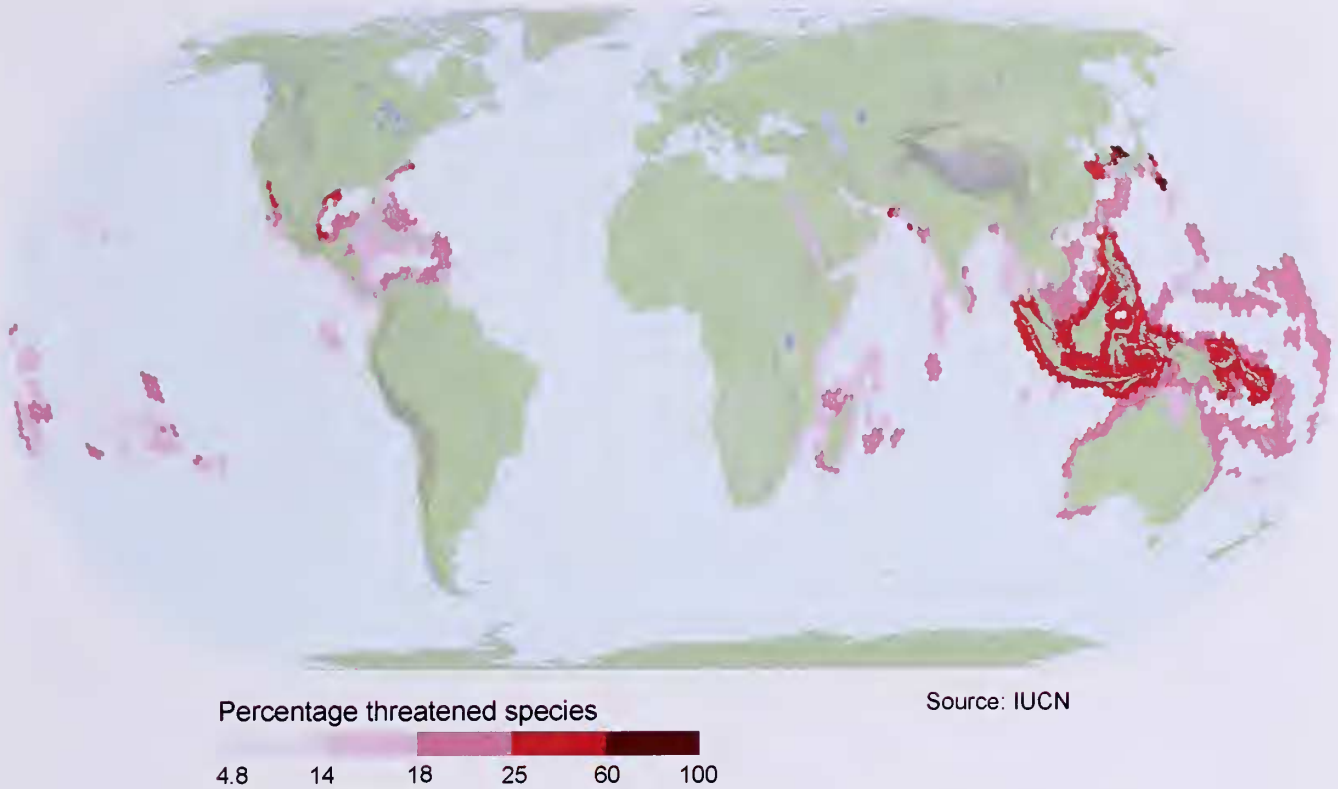

Fig. 8: Map showing the percentages of threatened reef-building coral species across the world

and also high percentages in threatened categories (Fig. 8). This region is also known as the epicentre of marine biodiversity and has the highest coral species richness. Coral reefs in the Caribbean region have been impacted by recent, rapid population decline of 2 key species: Staghorn Coral *Acropora cervicornis* and Elkhorn Coral *Acropora palmata*, both of which have been listed as Critically Endangered. In any region, the potential loss of these coral ecosystems will have huge cascading effects for reef-dependent species and for the large number of people and nations that depend on coral reef resources for economic and food security.

GLOBAL THREAT PATTERNS

Closer examination of some of these taxonomic groups reveals interesting patterns in the geographic concentrations of threatened across the globe. Fig. 9 shows the geographic patterns generated from overlaying the distributions of all threatened species in 4 taxonomic groups (birds, mammals, amphibians and corals). The contrast between the taxonomic groups demonstrates that geographic patterns of threat for one group do not predict the patterns of threat for another group; hence the importance of assessing the status of many groups of species.

There are important concentrations of threatened birds and mammals in South-east Asia, but the threat patterns of these two groups are markedly different in South America. Although nearly one-third of amphibians are at risk, threatened amphibians are found to be concentrated in a few areas only, especially in Mesoamerica, the northern Andes and the Greater Antilles. Conversely, most parts of the world have at least 1 threatened bird species, despite the fact that only 12% of birds are threatened.

LOOKING AT A FINER SCALE

The Red List criteria were developed for use at the global scale, at which the entire geographic range of a species is considered. However, IUCN is increasingly undertaking regional Red List projects. Regional and national lists are usually country-led initiatives and are not centralised in any way; they differ from each other widely in terms of scope and quality but can be very useful in guiding conservation work at subglobal levels.

In the Mediterranean region, for example, IUCN has assessed to date the following taxonomic groups: amphibians, reptiles, birds, mammals, sharks and rays, freshwater crabs and crayfish, endemic freshwater fishes, and dragonflies and damselflies (hereafter referred to collectively as dragonflies).

Overall, the proportion of threatened species in the Mediterranean (those classified as Critically Endangered, Endangered or Vulnerable), either at the global or regional

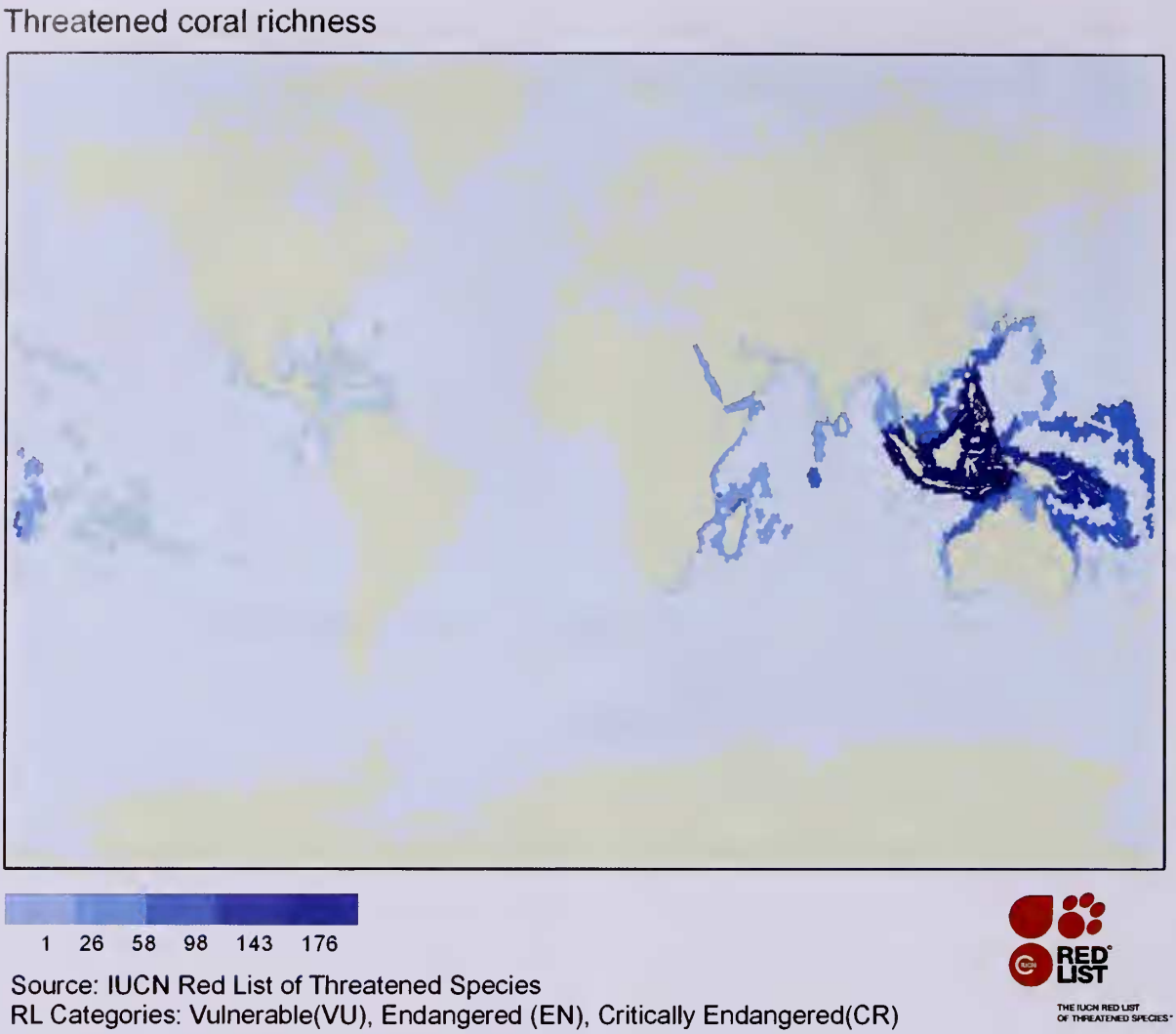

Fig. 9: The geographic patterns generated from overlaying the distributions of all threatened species in four taxonomic groups (birds, mammals, amphibians and corals)

level, is about one-fifth (19%), and about 1% of the species are already extinct in the region. These percentages will be higher if some of the currently Data Deficient species prove to be threatened, as is likely to be the case.

Freshwater species have been mapped based on river basins flowing into the Mediterranean Sea and adjacent Atlantic Ocean river basins. Fig. 10 indicates concentrations of species at risk, in particular in the Iberian Peninsula, the Balkans, the western part of Greece and the area from Turkey down to Israel and the Palestinian territories.

BROADENING THE COVERAGE OF BIODIVERSITY ASSESSMENTS

A new initiative is being employed to broaden the taxonomic coverage of the IUCN Red List in order to enable a better understanding of biodiversity status as a whole and to identify key regions and taxa that require greater conservation attention.

This approach takes a random sample of 1,500 species from different taxonomic groups (Baillie *et al.* 2008). It allows the identification of the general level of threat to each group, the mapping of areas likely to contain the most threatened species and the identification of the main drivers of threats and helps pinpoint what key actions are required to address declines in the group as a whole.

The results of both the comprehensive and sampled assessments are starting to provide new insights into our understanding of the status of the world's species that can be built upon to track changes over time. The current plans to expand the number of species assessed for the Red List, using both comprehensive and sampled techniques, will, when implemented, increase the number of assessed species from 45,000 (on the Red List in 2008) to 1,30,000 (Fig. 11).

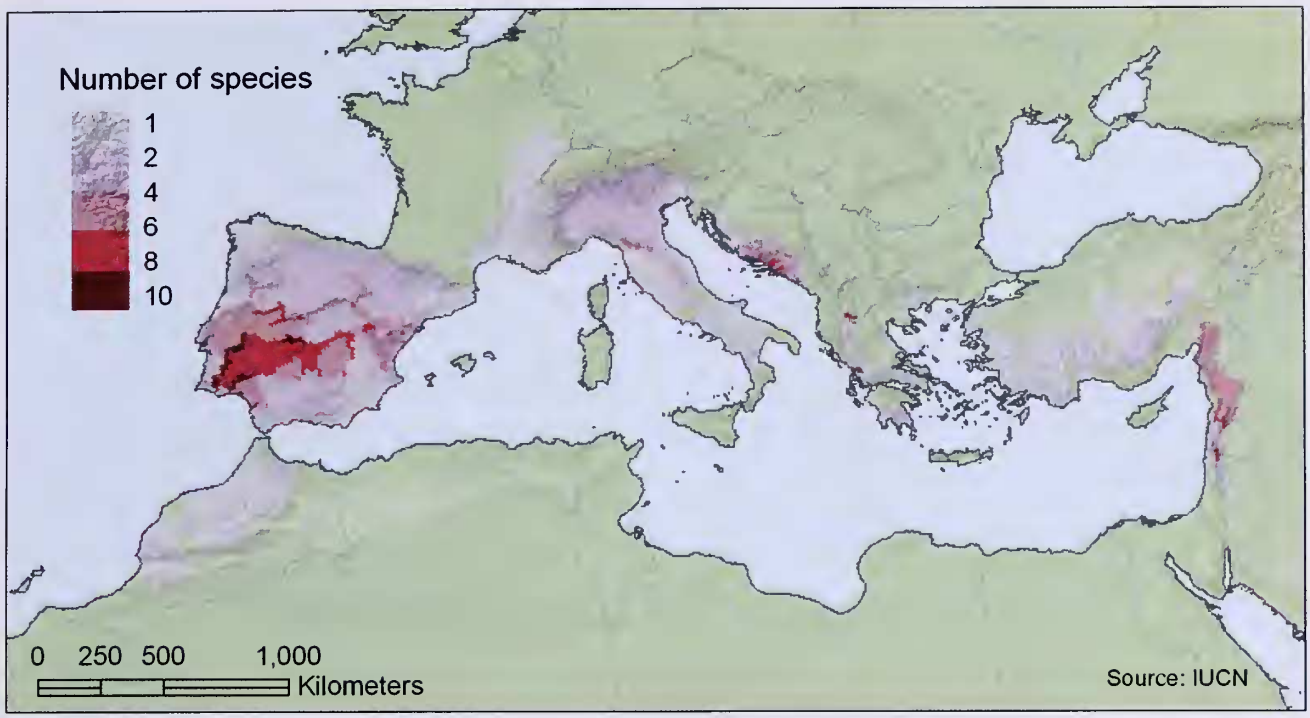

Fig. 10: Species richness of threatened freshwater amphibians, crabs, endemic fishes, mammals, dragonflies and reptiles in the Mediterranean basin

The first results of the sampled approach to Red Listing are now becoming available, specifically for reptiles and fishes, for neither of which the comprehensive assessments are complete yet. Across reptile groups, for example, the proportion of species threatened varies: 43% of crocodilians are threatened, compared with 12% of snakes and 20% of lizards. These patterns are likely to reflect differences in geography, range size, habitat specificity and biology, as well as threat intensity. Indo-Malaya is the most species-rich biogeographic realm for reptiles, and it also has the greatest density of threatened (CR, EN and VU) species (Fig. 12).

There are also some early results from this sampled approach for invertebrates. A map of the distribution of threatened freshwater crabs and dragonflies reveals some centres of threat for freshwater systems (Fig. 13). Marked concentrations of threatened species exist in Vietnam, Thailand, Cambodia, Malaysia and the Philippines in South-east Asia; Sri Lanka and the Indian Western Ghats in South Asia, and Colombia and Mexico in central and South America. These patterns are heavily influenced by the distribution of restricted range species.

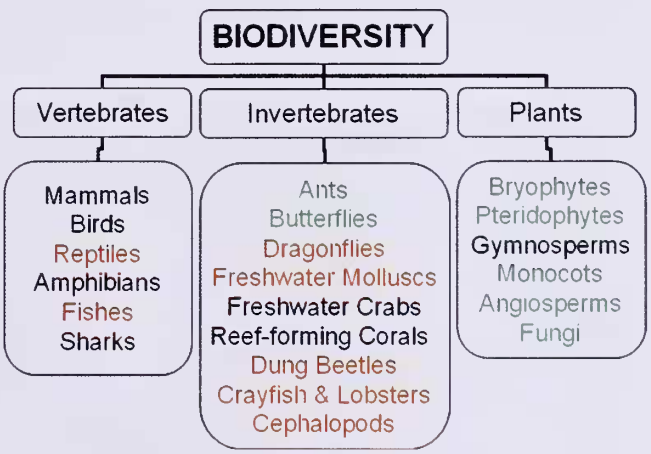

Fig. 11: Overview of IUCN Red List assessments: comprehensively assessed by 2008 (black); comprehensive assessments under way (red); statistically random samples planned or underway (green)

EXTINCTIONS

The global extinction of a species usually represents an end point in a long series of population extinctions. Creating an inventory of recent extinctions helps highlight the long list of unique species that have been lost forever. Understanding the extent of recent extinctions provides insights into historic extinction rates, which in turn can be compared to the rates over geological time to determine if current trends are normal or a cause for concern. An insight into the process of extinction can help us identify species that are at a risk of extinction and enable us to highlight taxonomic groups or species from specific regions that are or will be particularly prone to extinction.

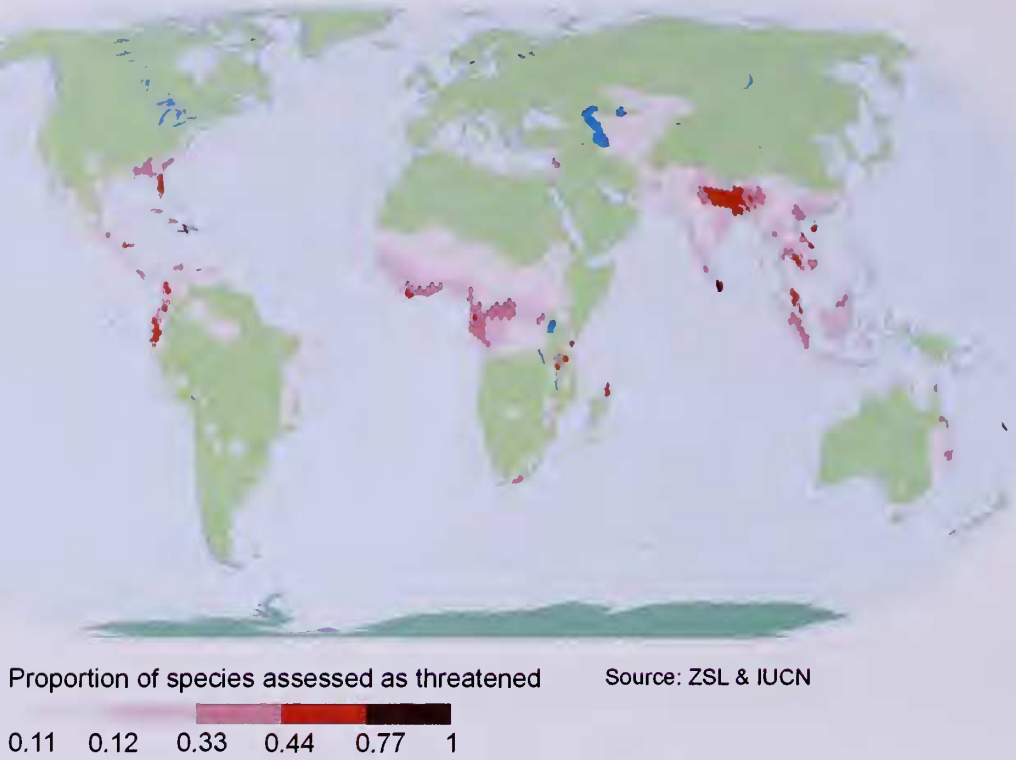

Fig. 12: Threatened species richness map for reptiles, based on a random sample of 1,500 species, 244 of which are threatened

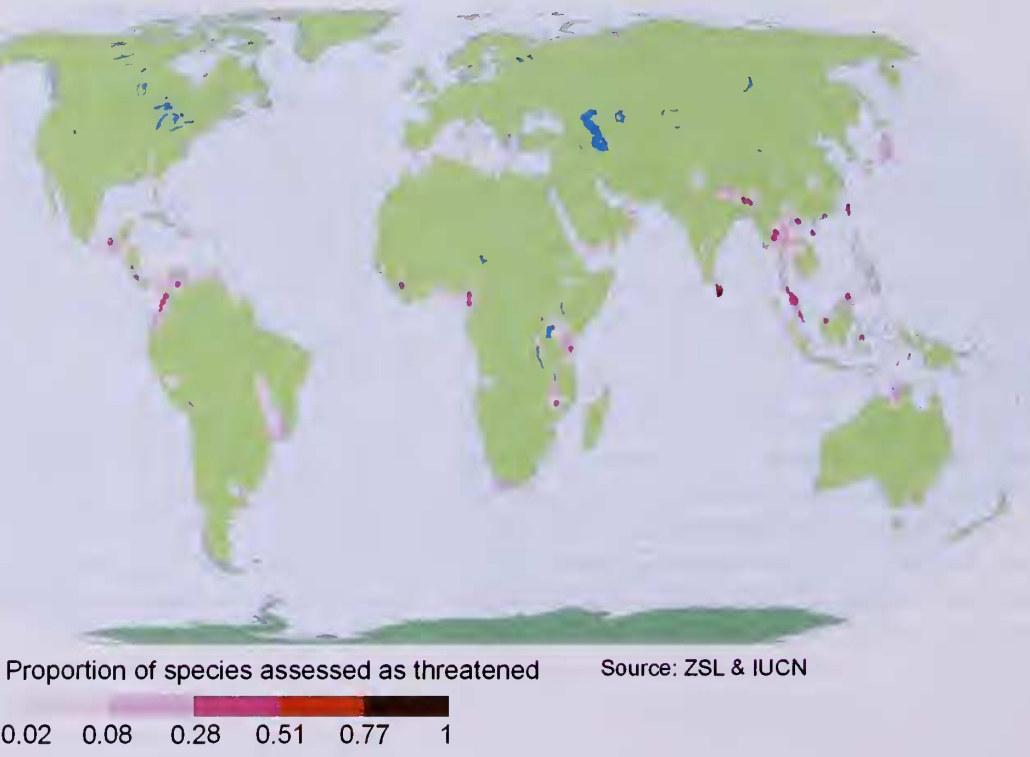

Fig. 13: Threatened species richness map for freshwater crabs (n = 210 species), and dragonflies and damselflies (n = 136 species)

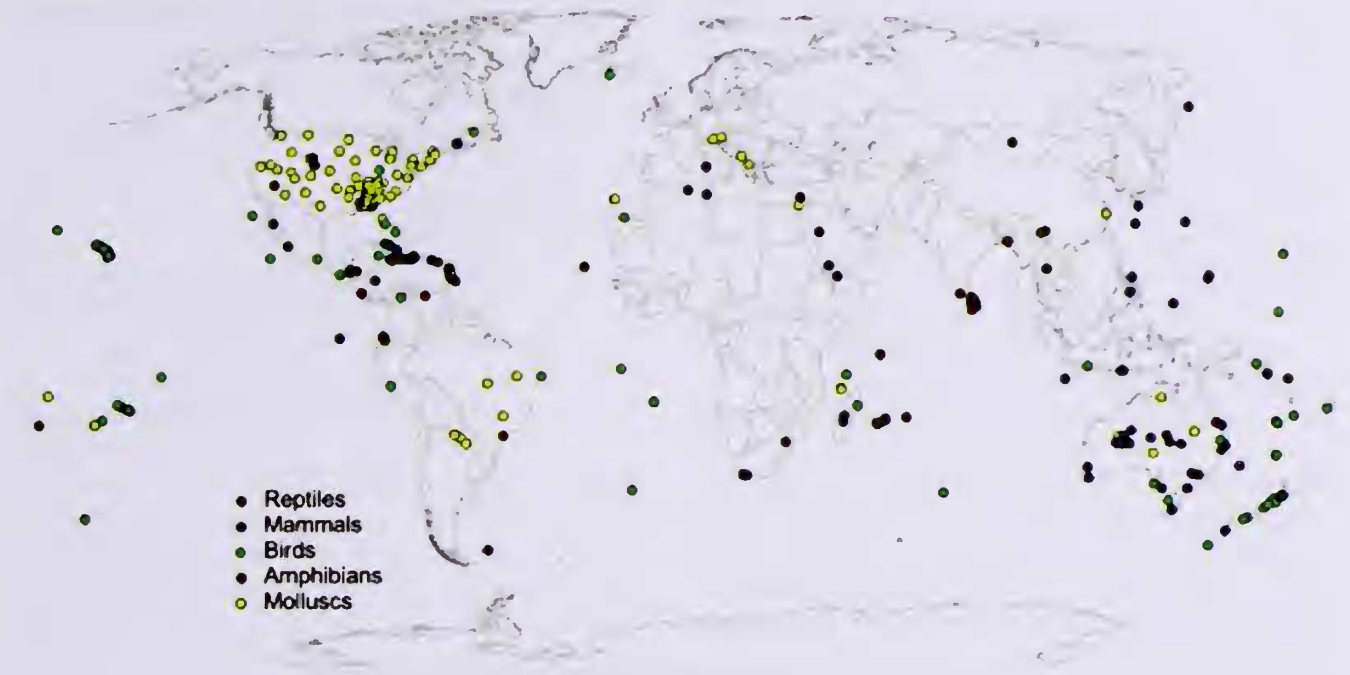

Fig. 14: The distribution of Extinct and Extinct in the Wild reptiles, mammals, birds, amphibians and molluscs

The world's list of documented extinctions continues to rise. The 2008 Red List includes 804 species listed as Extinct and 60 Extinct in the Wild. In the last 24 years there have been 29 documented extinctions, with recent extinction rates exceeding those from fossil records. With current extinction rates 100 to 1,000 times the natural (background) extinction rates, it is likely that the world is experiencing a net loss of species, perhaps for the first time in millions of years (Baillie *et al.* 2004).

There are major differences in the extinction patterns between the five taxonomic groups mapped in Fig. 14. Bird extinctions are overwhelmingly biased towards oceanic islands (including New Zealand), whereas the largest concentration of mammal extinctions is in Australia. Documented amphibian extinctions are focused on Sri Lanka, but this might be an artefact of under-recording extinctions elsewhere. Mollusc extinctions are concentrated in North American river systems, possibly another recording artefact. A detailed examination of bird extinctions since 1500 A.D. indicates that the pattern of extinctions might be changing. Although more than 80% of birds are found on continents, all extinctions prior to 1800 occurred on islands. This pattern has started to change in recent years, with more extinctions occurring on continents (Fig. 15).

THREATS

The major processes threatening species and driving extinctions are all of anthropogenic origin, and include habitat degradation and conversion (resulting in particular from agriculture, logging and residential and commercial development), overexploitation, invasive species, pollution and, increasingly, climate change (Figs 16, 17, 18).

Habitat loss and degradation are by far the greatest threat to amphibians at present (Fig. 16), affecting nearly 61% of all known amphibians (nearly 4,000 species), including 87% of the threatened amphibian species. The next most common threat to amphibians is pollution, which affects around one-fifth (19%) of amphibian species overall and 29% of threatened species. Although disease is a less common threat, it is much more likely to make a species globally threatened (Fig. 16). Indeed, the fungal disease

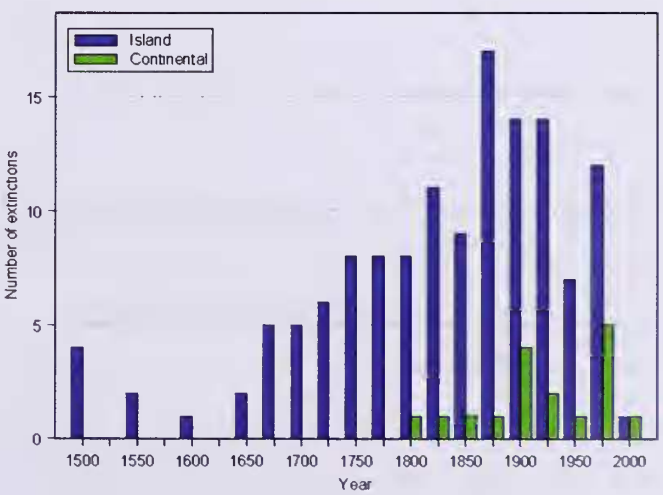

Fig. 15: The number of bird extinctions that have occurred on islands and continents since 1500 A.D.

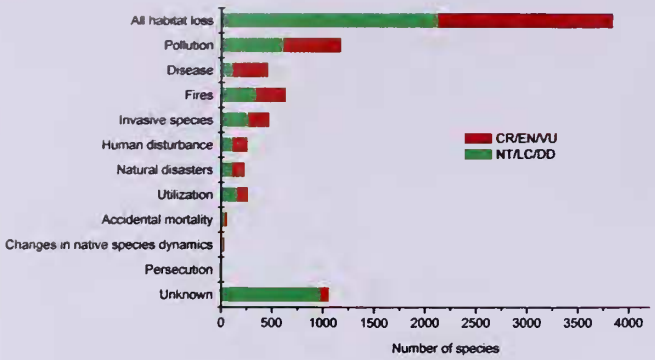

Fig. 16: Major threats to amphibians
(threatened species in red, non-threatened species in green)

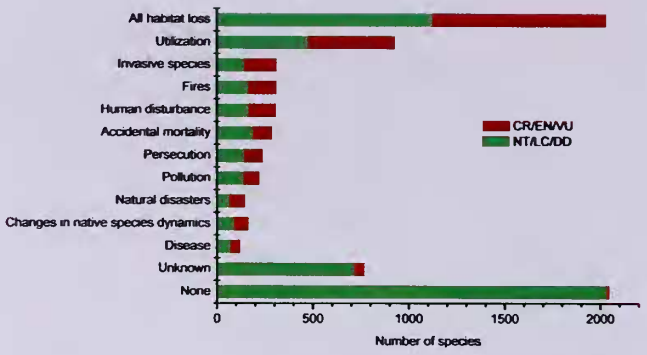

Fig. 17: Major threats to mammals
(threatened species in red, non-threatened species in green)

Chytridiomycosis is the major current driver of amphibian extinctions (Stuart *et al.* 2008).

By far the most significant threat to mammals is habitat loss, with over 2,000 species being negatively impacted (Fig. 17). The second most important threat is utilisation, with almost 1,000 species affected, mostly in Asia. The impact of invasive species is probably a little underestimated as only threats to extant species are included here and a significant proportion of species now considered extinct were affected by invasive species.

There is growing evidence that climate change will become one of the major drivers of species extinctions in the 21st century. IUCN is developing assessment tools to identify the potential effects of climate change on species. Susceptibility to climate change according to taxon-specific biological traits has been assessed, thereby allowing an

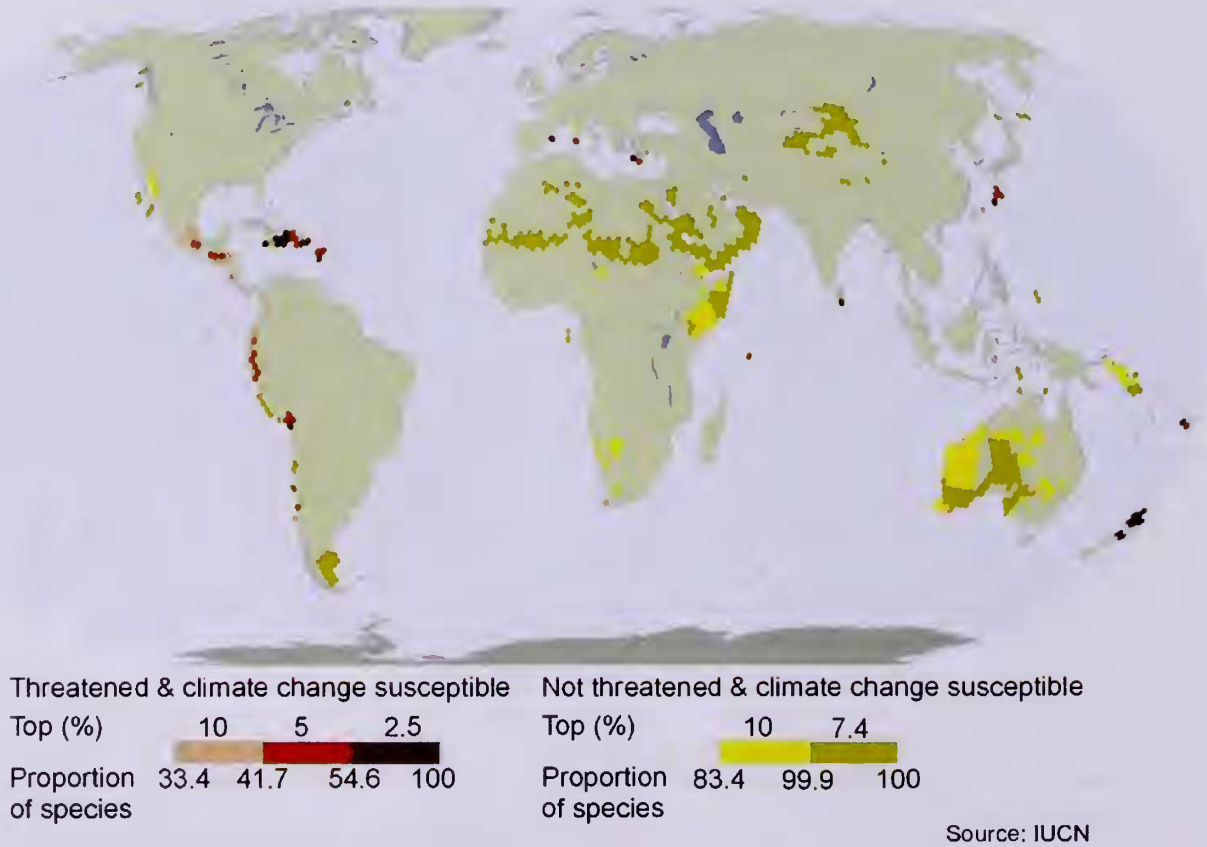

Fig. 18: Areas containing high proportions of threatened and 'climate change-susceptible' (reds) and not threatened and 'climate change-susceptible' amphibian species (yellows) (expressed as the percentage of species in these categories relative to the total number of species occurring there). High concentration areas indicate those with the top 10%, 5% and 2.5% of values, and when these were not distinguishable, the nearest appropriate percentages were used

analysis of the potential impacts of climate change on species based on an analysis of these traits (Foden *et al.* 2009 for details). Using expert assessments for birds (9,856 species), amphibians (6,222 species) and warm-water reef-building corals (799 species), the taxonomic and geographical distributions of the species most susceptible to climate change were examined and compared to the existing assessments of threatened species in the 2008 IUCN Red List of Threatened Species™ (herein The IUCN Red List; IUCN 2008).

For amphibians, mapping the richness of threatened and 'climate change-susceptible' species (Fig. 18) highlights Mesoamerica, the northern Andes and the Caribbean. Additional areas of high concentrations include several Mediterranean islands and south-western Turkey; Seychelles; the southern Japanese islands; New Zealand's North Island; and Fiji. Areas of high concentrations of species assessed as not threatened but 'climate change-susceptible' include western and central Australia; the Solomon Islands; south-eastern South America; north-western Mexico; the arid region extending from the Western Sahara through the Red Sea Basin, south to the Horn of Africa and along the coastal regions of the Arabian peninsula; and the foothills surrounding the northern Himalayan Plateau. These geographic regions are defined by concentrations of species that are likely to become threatened due to climate change but which are not yet 'picked up' as threatened in the IUCN Red List.

ARE SPECIES BECOMING MORE OR LESS THREATENED WITH EXTINCTION?

In those taxonomic groups about which we know most, species are sliding ever faster towards extinction. IUCN Red List Indices (RLI — Butchart *et al.* 2004, 2005, 2007) show that trends in extinction risk are negative for birds, mammals, amphibians and reef-building corals (Fig. 19). Many more species are moving closer towards extinction, as measured by their categories of extinction risk on the IUCN Red List. The groups vary in their overall level of threat; for example, amphibians have a higher proportion of species threatened (i.e., lower RLI values) compared with mammals. Groups also vary in their rate of deterioration, with the rapid declines in reef-building corals since 1996 being driven primarily by the worldwide coral-bleaching events in 1998 and subsequently (Carpenter *et al.* 2008; Polidoro *et al.* 2009). The RLI for birds show that there has been a steady and continuing deterioration in the status of the world's birds between 1988 and 2008. Over these 20 years, 225 bird species have been up-listed to a higher category of threat because of genuine changes in status, compared to just 32 species down-listed.

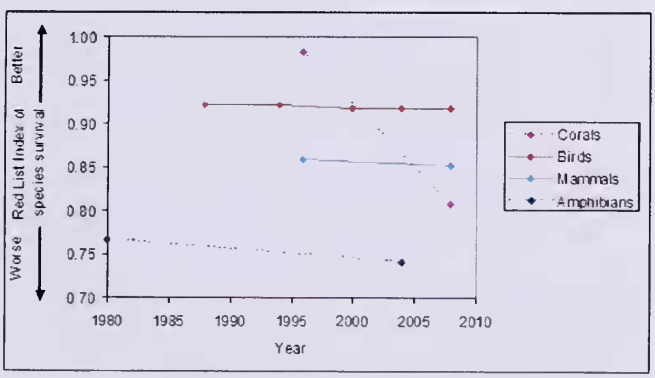

Fig. 19: Red List Index of species survival for corals, birds, mammals and amphibians, showing the proportion of species expected to remain extant in the near future without additional conservation action.
An RLI value of 1.0 equates to all species being categorized as Least Concern, and hence none being expected to go extinct in the near future. An RLI value of 0 indicates that all species have gone Extinct. (Number of non-Data Deficient species = 9,785 birds, 4,555 mammals, 4,416 amphibians and 704 corals (warm-water reef-building species only). Data are preliminary for amphibians in 1980 and corals in 1996.)

THREE CURRENT EXTINCTION CRISES

Looking at the Red List data as a whole, three major ongoing extinction crises are immediately evident, and these have already been highlighted in this paper. These are amphibians, corals and Asian large animals. There are probably other major crises also under way, but the Red List data are not yet complete enough to demonstrate this. Examples of likely crises include declines in marine species, especially due to bycatch, and declines of central and west African species due to bush meat harvesting.

Amphibians

As noted above, amphibians are the most threatened vertebrate group, with almost one-third of species listed as EX, EW, CR, EN or VU. At least 42% of all species are declining in population, indicating that the number of threatened species can be expected to rise in the future. In contrast, less than 1% of species show population increases. Although habitat loss clearly poses the greatest threat to amphibians, the fungal disease Chytridiomycosis is seriously affecting an increasing number of species and is the main driver of extinction over the last 3 decades (Stuart *et al.* 2008).

In response to the amphibian crisis, IUCN has developed the Amphibian Conservation Action Plan (Gascon *et al.* 2007). This provides a comprehensive framework for combating amphibian declines and extinctions. A major priority is to secure the habitats of the large number of threatened amphibian species that do not occur in any protected areas. There are at least 350, and possibly up to 600, such species, many more than is the case with birds or

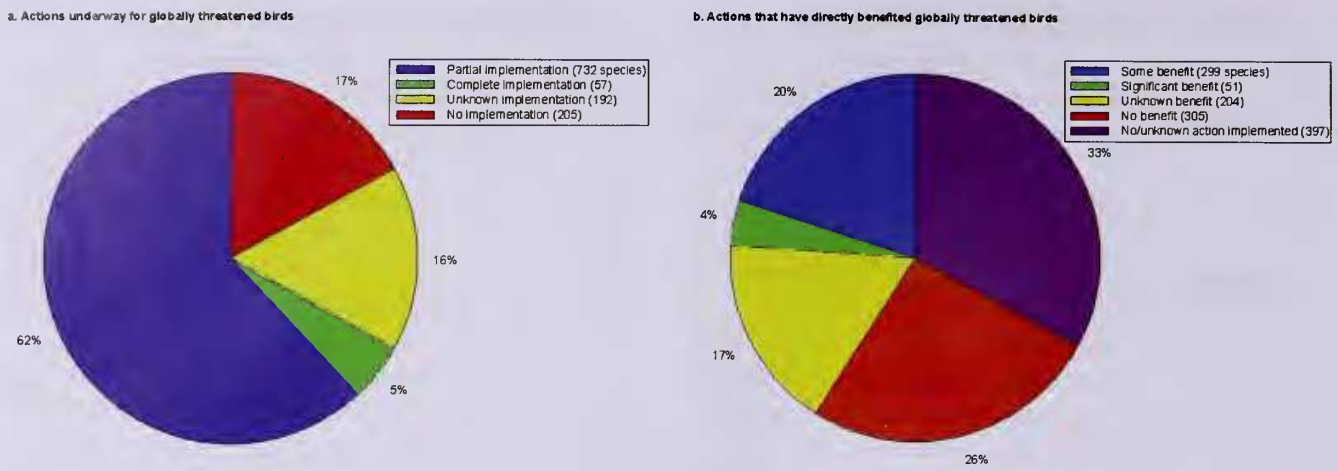

Fig. 20: Conservation action for birds: (a) percentage implementation and (b) percentage of those actions which have directly benefited threatened species

mammals (Rodrigues *et al.* 2004; Stuart *et al.* 2008). Furthermore, because of Chytridiomycosis, which cannot yet be treated in the wild and which can cause up to 100% mortality in certain species, many amphibian species can currently be saved only in captivity. This is obviously only an interim measure but one that, if successful, might buy some time for certain species while solutions to the Chytridiomycosis epidemic are sought. The Amphibian Ark Project (see http://www.amphibianark.org/) is a global programme to manage threatened amphibians in captivity until it is safe to reintroduce them into the wild.

Corals

The fastest rate of decline of the groups measured so far is seen in the reef-building corals. As mentioned above, the catastrophic declines in the abundance of corals are associated with bleaching and diseases driven by elevated sea surface temperatures. Coastal development and other human activities will have also impacted on the dramatic deterioration since the mid-1990s.

The impact of the decline and degradation of coral reefs on other reef-dwelling organisms is not yet known, but clearly the impacts on fishes and invertebrates could be alarming. Ex situ conservation might also prove to be necessary for corals and other coral-dependent species, especially as measures to reduce the level of CO_2 in the atmosphere are still a long way from having an effect.

Asian large animals

There have been massive decreases in wildlife populations in Asia in the last two decades, especially in South-east Asia and China. For example, there are now 10 Asian countries in the top 20 list for threatened mammals, and declines have also been most steep in the Indo-Malayan realm. The Indo-Malayan realm shows rapid declines in both birds and mammals, driven by the rapid increases in the rate of deforestation during the 1990s, particularly in the Sundaic lowlands of Indonesia and Malaysia, combined for mammals with high rates of hunting, particularly among medium- to large-bodied species. Indeed, there is a huge, and largely uncontained, threat of overexploitation affecting large-bodied taxa throughout Asia, including reptiles (including turtles) and fishes, as well as mammals and birds. Terrestrial, freshwater and marine species are all affected. There have been two likely mammalian extinctions in the last few years: the Baiji (or Yangtze River Dolphin) *Lipotes vexillifer* and the Kouprey *Bos sauveli*.

There is an urgent need throughout the region to address overexploitation through anti-poaching on the ground, as well as controlling trade in wildlife products. The loss of lowland forests for oil palm and other biofuels also needs to be addressed as a matter of urgency. In terms of addressing over harvesting, an initiative is needed not only to focus on anti-poaching (such as snare removal) but also to provide alternative livelihoods for local people, addressing the root causes of poaching, providing alternative protein sources and implementing capacity building and training programmes.

IS THERE ANY GOOD NEWS?

Looking at the raw Red List data can give misleading results, for example when comparing the headline statistics in 2007 and 2008. The number of threatened species has increased from 16,116 to 16,928 in association with the increase in species coverage from 41,415 species in 2007 to 44,838 in 2008. However, the overall proportion of threatened has dropped slightly, by 1%. Although this could represent

good news, an examination of the 223 species, which changed status for genuine reasons (i.e., became less threatened due to conservation efforts or became more threatened due to ongoing or increased threats), shows that only 40 of these were species that became less threatened, while 183 were listed in a higher category of threat.

Thirty-seven of the genuine improvements in status in 2008 were for mammals, with approximately 5% of threatened mammals demonstrating an increase in populations. It is estimated that 16 bird species have been prevented from going extinct between 1994 and 2004 due to conservation efforts; however, although (encouragingly) 67% of threatened species have some action under way, these actions have only benefited 24% of species so far (Fig. 20).

The 'take-home' message from these findings is that conservation can and does have a positive impact, but it is not yet being implemented at a level that can have a global impact on biodiversity trends.

DISCUSSION

Although a significant proportion of the world's species face extinction, it is not possible to quantify how many species are at risk because not all species have yet been named, the baseline checklists are constantly changing and the bulk of the world's species is yet to be assessed.

That said, the number of threatened species is increasing across virtually all the major taxonomic groups. Conservation measures are being taken for many species all over the world, ranging from species-specific actions to broad changes in national, regional or global policy. These responses in relation to individual threatened species are only just beginning to be measured, but many case studies show that well-focused species-centred actions can succeed in reducing the threat and improving the status.

The Red List species assessments are the most up-to-date, readily available and comprehensive inventory on species diversity. The information provided by the Red List shows what species are threatened, what the threats are and where they exist. Using this information to underpin conservation action will assist in preventing the decline of threatened species populations beyond the threshold of viability. With increasing knowledge of both where and how to act, focused conservation action works, although mitigating the extinction crisis will require much more rapid action. That means more resources, and resources better applied to safeguard habitats and improve the management of our natural resources.

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REFERENCES

Baillie, J. & B. Groombridge (Compilers and Editors) (1996): 1996 IUCN Red List of Threatened Animals. IUCN, Gland, Switzerland and Cambridge, UK. 368 pp.

Baillie, J.E.M., C. Hilton-Taylor & S.N. Stuart (Eds) (2004): 2004 IUCN Red List of Threatened Species. A Global Species Assessment. IUCN, Gland, Switzerland and Cambridge, U.K. 191 pp.

Baillie, J.E.M., B. Collen, R. Amin, H.R. Akçakaya, S.H.M. Butchart, N. Brummitt, T.R. Meagher, M. Ram, C. Hilton-Taylor & G.M. Mace (2008): Towards monitoring global biodiversity. *Conservation Letters 1*: 18-26.

Butchart, S.H.M., H.R. Akçakaya, J. Chanson, J.E.M. Baillie, B. Collen, S. Quader, W.R. Turner, R. Amin, S.N. Stuart & C. Hilton-Taylor (2007): Improvements to the Red List Index. *PLoS ONE2(1)*: e140. doi: 10.1371/journal.pone.0000140.

Butchart, S.H.M., A.J. Stattersfield, J.E.M. Baillie, L.A. Bennun, S.N. Stuart, H.R. Akçakaya, C. Hilton-Taylor & G.M. Mace (2005): Using Red List indices to measure progress towards the 2010 target and beyond. *Philosophical Transactions of the Royal Society, Series B 360*: 255-268.

Butchart, S.H.M., A.J. Stattersfield, L.A. Bennun, S.M. Shutes, H.R. Akçakaya, J.E.M. Baillie, S.N. Stuart, C. Hilton-Taylor & G. Mace (2004): Measuring global trends in the status of biodiversity: Red List Indices for birds. *Public Library of Science Biology 2(12)*: e383.

Carpenter, K.E., M. Abrar, G. Aeby, R.B. Aronson, S. Banks, A. Bruckner, A. Chiriboga, J. Cortés, J.C. Delbeek, L. DeVantier, G.J. Edgar, A.J. Edwards, D. Fenner, H.M. Guzmán, B.W. Hoeksema, G. Hodgson, O. Johan, W.Y. Licuanan, S.R. Livingstone, E.R. Lovell, J.A. Moore, D.O. Obura, D. Ochavillo, B.A. Polidoro, W.F. Precht, M.C. Quibilan, C. Reboton, Z.T. Richards, A.D. Rogers, J. Sanciangco, A. Sheppard, C. Sheppard, J. Smith, S. Stuart, E. Turak, J.E.N. Veron, C. Wallace, E. Weil & E. Wood (2008): One-third of reef-building corals face elevated extinction risk from climate change and local impacts. *Science 321*: 560-563.

DE GRAMMONT, P.C. & A.D. CUARÓN (2006): An evaluation of threatened species categorization systems used on the American continent. *Conservation Biology 20(1)*: 14-27.

DUDGEON, D., A.H. ARTHINGTON, M.O. GESSNER, Z.I. KAWABATA, D.J. KNOWLER, C. LÉVÊQUE, R.J. NAIMAN, A.-H. PRIEUR-RICHARD, D. SOTO, M.L.J. STIASSNY, & C.A. SULLIVAN (2006): Freshwater biodiversity: importance, threats, status and conservation challenges. *Biological Review 81*: 163-182.

DULVY, N.K., Y. SADOVY & J.D. REYNOLDS (2003): Extinction and vulnerability in marine populations. *Fish and Fisheries 4*: 25-64.

FODEN, W., G.M. MACE, J.-C. VIÉ, A. ANGULO, S.H.M. BUTCHART, L. DEVANTIER, H. DUBLIN, A. GUTSCHE, S. STUART & E. TURAK (2009): Species susceptibility to climate change impacts. Pp. 77-87. *In*: Vié, J.-C., C. Hilton-Taylor & S.N. Stuart (Eds): The 2008 Review of the Red List of Threatened Species. IUCN, Gland, Switzerland.

GASCON, C., J.P. COLLINS, R.D. MOORE, D.R. CHURCH, J.E. MCKAY & J.R. MENDELSON III (EDS) (2007): Amphibian Conservation Action Plan. IUCN/SSC Amphibian Specialist Group, Gland, Switzerland and Cambridge, UK.

IUCN (2008): IUCN Red List of Threatened Species. Available at: http://www.iucnredlist.org/.

LAMOREUX, J., H.R. AKÇAKAYA, L. BENNUN, N.J. COLLAR, L. BOITANI, D. BRACKETT, A. BRAUTIGAM, T.M. BROOKS, G.A.B. FONSECA & R.A. MITTERMEIER (2003): Value of the IUCN Red List. *Trends in Ecology & Evolution 18*: 214-215.

MACE, G.M., N.J. COLLAR, K.J. GASTON, C. HILTON- TAYLOR, H.R. AKÇAKAYA, N. LEADER-WILLIAMS, E.J. MILNER-GULLAND & S.N. STUART (2008): Quantification of extinction risk: IUCN's system for classifying threatened species. *Conservation Biology 22*: 1424-1442.

MILLENNIUM ECOSYSTEM ASSESSMENT (2005): Ecosystems and Human Wellbeing. Volume 1. Current Status and Trends. Island Press, Washington, DC.

POLIDORO, B.A., S.R. LIVINGSTONE, K.E. CARPENTER, B. HUTCHINSON, R.B. MAST, N. PILCHER, Y. SADOVY DE MITCHESON & S. VALENTI (2009): Status of the World's Marine Species. Pp. 55-65. *In*: Vié, J.-C., C. Hilton-Taylor & S.N. Stuart (Eds): The 2008 Review of the Red List of Threatened Species. IUCN, Gland, Switzerland.

ROBERTS, C.M. & J.P. HAWKINS (1999): Extinction risk in the sea. *Trends in Ecology and Evolution 14*: 241-246.

RODRIGUES, A.S.L., S.J. ANDELMAN, M.I. BAKARR, L. BOITANI, T.M. BROOKS, R.M. COWLING, L.D.C. FISHPOOL, G.A.B. FONSECA, K.J. GASTON, M. HOFFMANN, J.S. LONG, P.A. MARQUET, J.D. PILGRIM, R.L. PRESSEY, J. SCHIPPER, W. SECHREST, S.N. STUART, L.G. UNDERHILL, R.W. WALLER, M.E.J. WATTS & X. YAN (2004): Effectiveness of the global protected area network in representing species diversity. *Nature 428*: 640-643.

RODRIGUES, A.S.L., J.D. PILGRIM, J.F. LAMOREUX, M. HOFFMANN & T.M. BROOKS (2006): The value of the IUCN Red List for conservation. *Trends in Ecology and Evolution 21(2)*: 71-76.

SCHIPPER, J., J.S. CHANSON, F. CHIOZZA, N.A. COX, M. HOFFMANN, V. KATARIYA, J. LAMOREUX, A.S.L. RODRIGUES, S.N. STUART, H.J. TEMPLE, J. BAILLIE, L. BIOTANI, T.E. LACHER JR., R.A. MITTERMEIER, A.T. SMITH, D. ABSOLON, J.M. AGUIAR, G. AMORI, N. BAKKOUR, R. BALDI, R.J. BERRIDGE, J. BIELBY, P.A. BLACK, J.J. BLANC, T.M. BROOKS, J.A. BURTON, T.M. BUTYNSKI, G. CATULLO, R. CHAPMAN, Z. COKELISS, B. COLLEN, J. CONROY, J.G. COOKE, G.A.B. DA FONSECA, A.E. DEROCHER, H.T. DUBLIN, J.W. DUCKWORTH, L. EMMONS, R.H. EMSLIE, M. FESTA-BIANCHET, M. FOSTER, S. FOSTER, D.L. GARSHELIS, C. GATES, M. GIMENEZ-DIXON, S. GONZALEZ, J.F. GONZALEZ-MAYA, T.C. GOOD, G. HAMMERSON, P.S. HAMMOND, D. HAPPOLD, M. HAPPOLD, J. HARE, R.B. HARRIS, C.E. HAWKINS, M. HAYWOOD, L.R. HEANEY, S. HEDGES, K.M. HELGEN, C. HILTON-TAYLOR, S.A. HUSSAIN, N. ISHII, J.A. JEFFERSON, R.K.B. JENKINS, C.H. JOHNSTON, M. KEITH, J. KINGDON, D.H. KNOX, K.M. KOVACS, P. LANGHAMMER, K. LEUS, R. LEWISON, G. LICHTENSTEIN, L.F. LOWRY, Z. MACAVOY, G.M. MACE, D.P. MALLON, M. MASI, M.W. MCKNIGHT, R.A. MEDELLIN, P. MEDICI, G. MILLS, P.A. MOEHLMAN, S. MOLUR, A. MORA, K. NOWELL, J.F. OATES, W. OLECH, W.R.L. OLIVER, M. OPREA, B.D. PATTERSON, W.F. PERRIN, B.A. POLIDORO, C. POLLOCK, A. POWEL, Y. PROTAS, P. RACEY, J. RAGLE, P. RAMANI, G. RATHBUN, R.R. REEVES, S.B. REILLY, J.E. REYNOLDS III, C. RONDININI, R.G. ROSELL-AMBAL, M. RULLI, A.B. RYLANDS, S. SAVINI, C.J. SCHANK, W. SECHREST, C. SELF-SULLIVAN, A. SHOEMAKER, C. SILLERO-ZUBRI, N. DE SILVA, D.E. SMITH, C. SRINIVASULU, P.J. STEPHENSON, N. VAN STRIEN, B.K. TALUKDAR, B.L. TAYLOR, R. TIMMINS, D.G. TIRIRA, M.F. TOGNELLI, K. TSYTSULINA, L.M. VEIGA, J.-C. VIÉ, E.A. WILLIAMSON, S.A. WYATT, Y. XIE & B.E. YOUNG (2008): The status of the world's land and marine mammals: diversity, threat and knowledge. *Science 322(5899)*: 225-230.

STUART, S.N., M. HOFFMANN, J.S. CHANSON, N.A. COX, R.J. BERRIDGE, P. RAMANI & B.E. YOUNG (EDS) (2008): Threatened Amphibians of the World. Lynx Edicions, Barcelona, Spain; IUCN, Gland, Switzerland, and Conservation International, Arlington, Virginia, USA.

VIÉ, J.-C., C. HILTON-TAYLOR, C. POLLOCK, J. RAGLE, J. SMART, S. STUART & R. TONG (2009): The IUCN Red List: a key conservation tool. Pp. 1-13. *In*: Vié, J.-C., C. Hilton-Taylor & S.N. Stuart (Eds): The 2008 Review of the Red List of Threatened Species. IUCN, Gland, Switzerland.

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CONSERVATION STATUS OF THE LAST SURVIVING WILD POPULATION OF HANGUL OR KASHMIR DEER *CERVUS ELAPHUS HANGLU* IN KASHMIR, INDIA

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The Kashmir Deer or Hangul *Cervus elaphus hanglu*, a critically endangered deer, is one of the four easternmost subspecies of Red Deer found in Asia and is endemic to the mountains of Kashmir in the north-western Himalayan region of India. At present, the only viable Hangul population is confined to the 141 sq. km Dachigam National Park (NP), with a few isolated Hangul herds in its adjoining protected areas. Here, we present our recent (2001-2008) assessment of the Hangul's status and conservation in the Kashmir region based on intensive monitoring in Dachigam NP and extensive surveys carried out all over the Hangul's erstwhile stronghold and range. Our range-wise surveys indicate that at present the last surviving and genetically viable Hangul population of 140-170 individuals is restricted to Dachigam NP. A few isolated Hangul populations are also present in the adjoining conservation reserve areas of Bren-Nishat (11 Hangul), including Cheshmashahi Forest Reserve, south-west of Dachigam NP, where a direct sighting of two Hangul females was made in autumn; Khrew (2-6 Hangul); Khanagund (1-2 Hangul); Shikargah (7-12 Hangul) and Overa Wildlife Sanctuary (6 Hangul). Besides, Hangul use the Surfrao and Akhal blocks of Sindh Forest Division, north-east of Dachigam NP, during spring and summer. A group of about 12 Hangul was sighted north of the holy Amarnath cave, which falls just outside the demarcated boundaries of the Overa-Aru and Baltal-Thajwas wildlife sanctuaries, east of Dachigam NP. The current population trends indicate that the species could go extinct if the necessary serious interventions are not made immediately. This study attributes the decline in Hangul population to low breeding, female biased sex ratio, the problem of survival of the young, inadequate recruitment of fawns to adulthood due to factors such as considerable predation by the Leopard *Panthera pardus* and Asiatic Black Bear *Ursus thibetanus*, poaching and continued degradation of Hangul summer habitats in Upper Dachigam, along with biotic interference in winter habitats, and the movements of Hangul in summer to unprotected areas in Sindh Forest Division outside Dachigam NP and the excessive biotic interferences therein. Significant parasitic infestations have also been found in faecal samples of Hangul in Dachigam NP. The Hangul population in Dachigam NP and its adjoining areas thus needs immediate attention. An intensive population monitoring programme, studies of the reproductive ecology and movement patterns of the Hangul and monitoring its health to understand better the factors affecting the population growth and biology and other aspects of Hangul ecology are required for effective management and long term conservation. Population studies indicate a decrease in genetic heterozygosity over time and thus there is a need for urgent measures to arrest the loss in heterozygosis and declining trend of the Hangul population. There is an urgent need for a Hangul recovery plan to be developed that includes field surveys to identify corridors to help dispersion and reintroduction of Hangul to its former distribution range and habitat protection in Upper Dachigam and other potential Hangul habitats outside Dachigam. A captive breeding plan for the Hangul is important to repopulate existing good habitats in the Hangul range, beginning with the Shikargah-Overa ranges in Lidder Valley.

Key words: Hangul, *Cervus elaphus hanglu*, Red Deer, Dachigam, viable population, Zanskar Range, Kashmir

INTRODUCTION

The Hangul or Kashmir Stag *Cervus elaphus hanglu*, listed as a critically endangered deer in the IUCN's Red Data Book (Simon 1966; IUCN 2006), is one of the four easternmost subspecies of Red Deer that are found in Asia (Grzimek 1990; Geist 1998). However, unlike Red Deer and Wapiti *Cervus canadensis*, which have a wider distribution, extending from western Europe to central Asia, and North America and Canada (Ellerman and Morrison-Scott 1951; Flerov 1952; Corbet 1978), the Hangul has had a restricted global distribution. Being endemic to Kashmir, it was once distributed widely in the mountains of Kashmir (Gee 1965; Schaller 1969) along the Zanskar mountain range in the North-West Himalayan Biogeographic Zone (2A) (Rodgers and Panwar 1988) of India. The shikar map of Kashmir prepared by the then Maharaja of Jammu and Kashmir, Hari Singh, depicts the past distribution of the Hangul in an arc of 64 km width, north and east of the Jhelum and the lower Chenab river. The distributional range extended from Shalurah and Karen in the Kishenganga catchment over to Dorus in Lolab Valley and the Erin catchments in Bandipora in the north to

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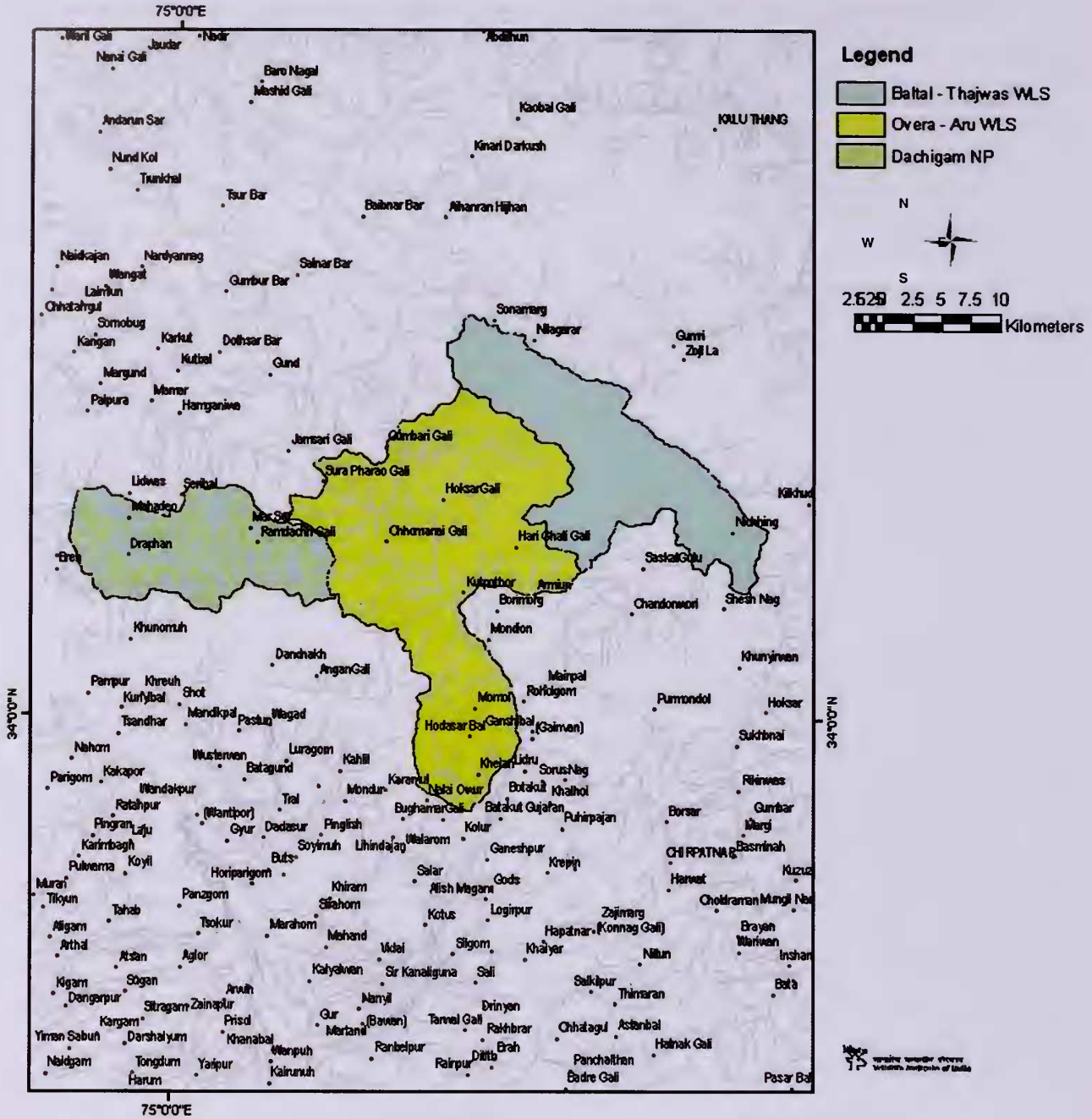

Fig. 1: Dachigam National Park and adjoining Protected Areas

Marwah/Wadwan in Kishtwar High Altitude National Park (NP) in the lower Chenab Valley, and Ramnagar in the south (Lydekker 1924; Holloway and Schaller 1970; Holloway and Wani 1970) (Figs 1, 3) through the present day Baltal-Thajwas Wildlife Sanctuary (WS), Tral Conservation Reserves (Shikargah, Panner & Khiram), Overa-Aru WS, Desu WS and Rajpariyan (Daksum) WS. The Gamgul Siya-Behi Sanctuary in Himachal Pradesh, on the state border, was the only area outside Jammu and Kashmir that probably retained a few Hangul (Holloway 1971).

During the recent past, the Hangul appears to have been wiped out from its past distribution range, possibly due to large scale biotic interference owing to habitat fragmentation and degradation, and poaching. At present a viable population of Hangul occurs only in Dachigam NP, with a few isolated populations in the adjoining areas.

The estimated population of Hangul in Kashmir in 1900 was 3,000-5,000 and in 1947, there were *c.* 2,000 Hangul still surviving. But 10 years later, the population drastically reduced to about 400 individuals (Gee 1966). The estimates

of the Hangul population between 1969 and 1970 range from not more than 180 individuals (Schaller 1969) to 140-170 (Holloway 1971).

Estimates over the years of the Hangul population in Dachigam and adjoining areas show wide fluctuations, with a drastic decline during the recent past from the 1980s (Fig. 2). The decline in the Hangul population from 2,000 in 1947 (Gee 1965) to 140-170 in 1970 (Holloway 1971) and 175 in 1992 has been attributed to the continued degradation of the Hangul's summer habitat of Upper Dachigam (Holloway 1971; Kurt 1978) and the continued irregular biotic interference in its winter habitat of Lower Dachigam in the past, besides excessive poaching.

Despite the critically endangered status of the Hangul, the species had been very poorly studied compared to its conspecifics the Red Deer of Europe and Wapiti, and other deer species in India. Some information, however, existed on the Hangul, mostly in the form of brief accounts by hunters (Ward 1921; Stockley 1936) stressing shooting exploits and naturalists stressing conservation problems (Talbot 1959; Gee 1965; Schaller 1969; Holloway and Schaller 1970; Holloway and Wani 1970; Caughley 1970; Kurt 1978; Oza 1977; Shah *et al.* 1984; Mishra 1986; Iqbal 1986; Inayatullah 1987). Some accounts deal with general information about the Hangul (Lydekker 1915; Flerov 1952; Whitehead 1972; Lowe and Gardiner 1974; Schaller 1977; Groves and Grubb 1987; Geist 1998) with the exception of the few brief survey reports and natural history accounts mentioned above, carried out prior to the 1990s, and the routine annual Hangul population census carried out by the Wildlife Protection Department of the Jammu & Kashmir Government, no intensive studies had been carried out on the aspects of Hangul ecology prerequisite for its effective long term survival and conservation planning. Here, we present the results of our surveys (2001-2008) and intensive study on Hangul ecology in Dachigam NP and the Hangul's erstwhile distributional range in Kashmir. We also summarize the critical factors that affect the Hangul and its habitat and are prerequisite for the effective management and long term conservation and survival of the Hangul and its habitat.

STUDY AREA

The area of the intensive study, Dachigam NP, holding the last genetically viable population of the Hangul, lies between 34° 05' 00" N to 34° 10' 32" N and 74° 53' 50" E to 75° 09' 16" E. The mountain ranges enclosing Dachigam NP are a part of the great Zanskar Range, which forms the north-west branch of the Central Himalayan Axis, bifurcating near Kullu (Himachal Pradesh) and terminating in the high twin peaks of Nun Kun (7,135 m). The entire Hangul distributional range is characterised by complex crystalline rocks, granites, gneisses and schists which form the core of the Zanskar Range, a fold of which encloses the Dachigam NP. This complex is partly sedimentary and consists of slates, phyllites and schists with embedded crystalline limestone (Lydekker 1876). Most of the sediments composing these ranges have been laid from the Cambrian to the Tertiary period, and ridged and folded up over the ages (Wadia 1961). The area exhibits a variety of vegetational types characterised by the habitat, form and density of dominant species and controlled by a number of factors including habitat conditions, exposure, altitude and, above all, the degree of biotic interference (Singh and Kachroo 1978). The low lying areas, from 1,700 to 3,000 m, have a complex mixture of vegetation types, with broad leaf mesophyll forests of *Acer caesium*, *Morus alba*, *Ulmus* spp., *Rhus succidiadiana*, and *Juglans regia*, *Parrotiopsis jacquemontiana* and a variety of conifers such as Deodar *Cedrus deodara*, Blue Pine *Pinus wallichiana*, Spruce *Picea smithiana* and Fir *Abies pindrow* growing in an altitudinal sequence (Holloway 1971; Singh and Kachroo 1978). The upper reaches, from 3,000 to *c.* 4,700 m, comprise a vegetation gradient of a subalpine forest community followed by scrub vegetation of Birch *Betula utilis* and Rhododendron *Rhododendron* spp. interspersed with herb-rich grasslands and meadows above 3,300 m. This zone gradually merges into the zone of permanent snow, which is above 3,500 m (Holloway 1971; Singh and Kachroo 1978). The main vegetation types in the area as per Champion and Seth (1968) are typical of Himalayan moist temperate forests: they are of the subalpine forest and alpine forest types.

The climate of the study area may be described as sub-Mediterranean to typically temperate, with higher degrees of variation in precipitation and dryness. Generally, two spells of dryness are experienced, one in June and another in September-November. Snow is the main source of precipitation and in some parts melts till June. Four distinct seasons occur in a year: spring (March-May), summer (June-August), autumn (September-November) and winter (December-February). The monthly mean temperatures recorded during the study period ranged between a maximum of 32 °C in August 2002 (late summer) and a minimum of -5.8 °C during January 2003 (mid-winter) (Ahmad 2006). The soil depth on the slope in the study area from the lower to the middle reaches is less than 25 cm, and hence falls under the category of very shallow soils (Bhat 1985). The annual minimum and maximum rainfall of Dachigam and adjoining areas have been calculated as ranging between 32 mm and 546 mm (Bhat 1985).

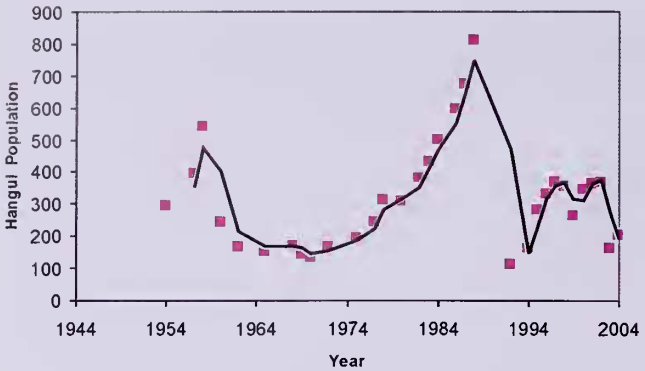

Fig. 2: Population trend in Dachigam and adjoining areas from 1954 to 2004 (Gee 1966; Holloway 1971; Kurt 1969; Department of Wildlife Protection 1970 till 2004; Qureshi and Shah 2004; Ahmad 2006: this study)

METHODOLOGY

This ecological study on the Hangul was aimed at enhancing the scientific knowledge on the aspects of Hangul ecology that are prerequisite for its effective management and long term conservation. We carried out intensive studies on Hangul ecology in Dachigam NP on a regular basis (2001-2004) besides extensive surveys (2004-2008) in the Hangul's erstwhile range areas, including Dachigam NP. Hangul distribution, abundance, habitat use, food and feeding habits were investigated along stratifies trails/transects (1 to 2 km length), and survey blocks, on a rotational basis 3-4 times a month in different day hours. For intensive studies in Dachigam NP, the study area was stratified into 7 transects varying in length between 1 and 2 km and in 7 survey blocks (Fig. 4), based on differences in altitude, slope, aspect, floristic composition, degree of human disturbance and administrative beat. Each transect was monitored on a rotational basis three times a month according to the line transect method (Burnham *et al.* 1980), and blocks were intensively surveyed along trails, *nullahs* (streams) and contours according to the trail monitoring method (Rutledge 1982) on a rotational basis four times a month in different seasons and different time periods of the day, for data collection and investigations on Hangul distribution, abundance, habitat use, food and feeding habits. Data based on direct Hangul sightings were collected on these transects and survey blocks. For each sighting, several parameters were recorded, including the time of animal sighting, group size and group composition (males, females, young/yearlings and unknown sex). Besides, data on indirect evidence of Hangul (dung/pellets) wherever found were also collected in 59 (2 × 20 m) belt transects randomly laid in 5 survey blocks for habitat use and dietary investigations. Attempts were also made to investigate the feeding habits of Hangul based on scan sampling following Altman (1952) or following the groups.

Besides the intensive surveys in Dachigam NP, an extensive reconnaissance of the erstwhile stronghold areas of the Hangul's pre-1947 distributional range was carried out to assess the present status and distribution of the Hangul outside Dachigam NP. The survey areas were selected based on unconfirmed reports from the Hangul's past distributional range areas, extending from Keran in the Kishanganga catchment area and Dorus in Lolab Valley of Bandipora to Kishtwar NP. The areas covered in the surveys and interviews with local people and livestock herders include (1) Surfrao and Akhal forest blocks of Sindh Forest Division, and Baltal-Thajwas WS, north and north-east of Dachigam NP; (2) Brein, Nishat and Cheshmashahi Conservation Reserve to the west and south-west of Dachigam NP; (3) Hajan and Satura blocks of Tral Conservation Reserve and Shikargah/Panner Conservation Reserves south-east of Dachigam NP; and (4) Overa-Aru WS in the far eastern part of Dachigam NP (Fig. 1).

In each of these areas, the survey units were selected based on unconfirmed reports of Hangul presence available with the forest and wildlife staff and local people. A forest and wildlife beat was considered as a unit for sampling Hangul presence and habitat assessment (Jhala *et al.* 2005). Furthermore, to ascertain the status of the Hangul in its western range areas, we interviewed local people, livestock herders and army personnel deployed in Gurez and Bandipora about the past and current occurrence of the Hangul.

Hangul habitat suitability and biotic interference assessment was also carried out in Dachigam NP and its adjoining areas to identify the potential units in the Hangul's past distribution range areas outside Dachigam NP for relocation/reintroduction of some Hangul and the possibility of monitoring them continuously.

Hangul relative abundance was estimated following Burnham *et al.* (1980). The chi-square test and ANOVA were performed for analysis of population data. All statistical analyses were performed using the computer program SPSS following Norris (1990). The typical group size was computed following Jarman (1974). Hangul densities were estimated from the Hanguls seen on the transects. Visibility correction was not employed. These densities are merely relevant in terms of relative comparisons. The Hangul population viability analysis (PVA) and the possible risk of extinction of the Hangul in the near future was evaluated using the widely used structured PVA (Caughley 1994; Akcakaya 2000a,b) with the help of the software program Vortex 9.6 (Lacy 2000). This model was run on the basis of population characteristics reported for the Red Deer and Hangul, including data gathered for the Hangul during this study.

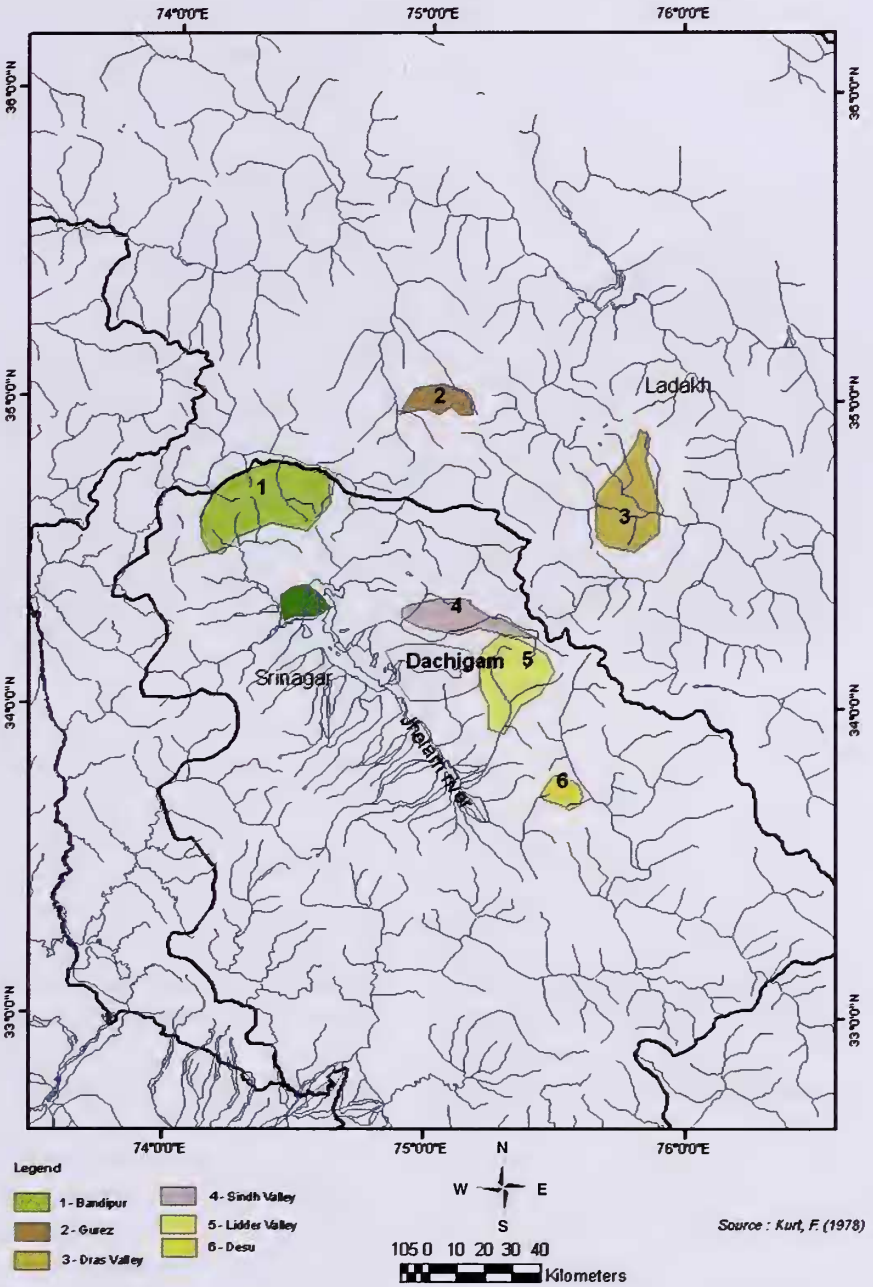

Fig. 3: Past distribution of Hangul in Kashmir Valley

During our intensive studies in Dachigam NP, 693 surveys in the form of trail or transect monitoring were carried out in 7 transects and 5 fixed survey blocks that involved a time and distance effort of 1,839 hours and 5,668 km, respectively, distributed almost equally in the 4 seasons (416 hours and 1,263 km in spring; 473 hours and 1,428 km in summer; 418 hours and 1,276 km in autumn; and 532 hours and 1,701 km in winter).

RESULTS

Our intensive studies and extensive range-wise surveys in almost all the erstwhile areas of the Hangul in Kashmir clearly indicate that at present the last genetically viable population of the Hangul occurs only in the 141 sq. km Dachigam NP in Kashmir and that a few isolated populations occur in the adjoining conservation reserves of Bren-Nishat (11 Hangul), including Cheshmashahi Forest Reserve, south-west of Dachigam NP, Khrew (4-6 Hangul); Khanagund (1-2 Hangul); and Shikargah (7-12 Hangul) and in Overa WS (*c.* 6 Hangul). Besides, some stray Hangul groups have been sighted in Sindh Forest Division to the north and north-west of Dachigam NP, including 6 Hangul (1 male, 3 female and 2 young) sighted on the trail between Surfrao and Akhal

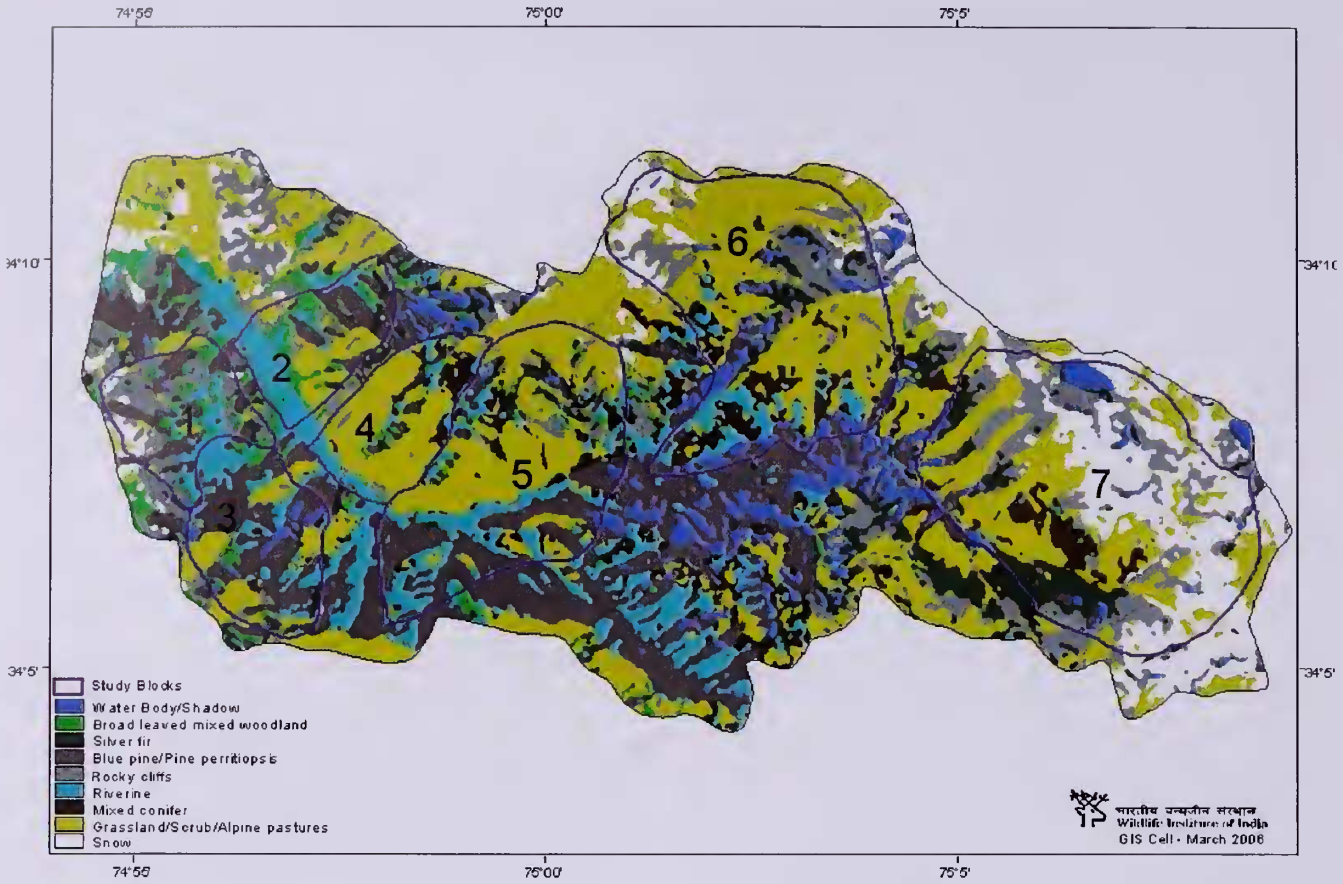

Fig. 4: Location of study blocks in DNP

blocks of the Sindh Forest Division. Of 5 Hangul individuals which fell into the Sindh river near Kangan Forest Block in June 2006, 2 females were rescued and brought to Pahalgam Zoo, in south Kashmir; these were subsequently preyed upon by Leopard *Panthera pardus*.

In 2004, we estimated the Hangul population to be between 146 and 249, with a mean of 197 animals. In 2006, the Hangul population was estimated between 117 and 190 animals, with a mean of 153 animals, whereas in 2008 the population estimates turned out to be between 170 and 190 animals. There appears to be a marginal decline in the Hangul population between 2004 and 2006, which is statistically significant (t=2.24, P=0.06). The Hangul population showed a decreasing trend in recent years in Dachigam and adjoining areas.

In Dachigam NP, during February 2001 to December 2004, a total of 326 Hangul sightings were recorded, and the maximum Hangul sightings (101) were recorded in winter, followed by 85 Hangul sightings each in spring and autumn. During summer only 55 Hangul sightings were recorded. Hangul encounter rates both per hour effort and per kilometre walk showed a decrease from spring to summer, followed by a gradual increase from summer through autumn to winter. The maximum Hangul encounter rates (2.02 individuals/hour effort and 0.67 individuals/km walk) were recorded in spring, followed by 1.17 individuals/hour effort and 0.55 individuals/km walk recorded in winter. The minimum encounter rates of 0.41 individuals/hour effort and 0.14 individuals/km walk were recorded in summer. Hangul encounter rates/hour effort or per kilometre walk showed significant differences between different seasons (F=42.218, P=0.001 and F=42.44, P=0.001, respectively). The overall Hangul encounter rates/hour effort and per kilometre walk also showed significant differences between the study blocks (F=173.71, P=0.001 and F=193.37, P=0.001, respectively). The overall (weight for block area) Hangul density in the intensive study area of Dachigam NP was 5.60±1.13 SE Hangul/sq. km, and it varied between the seasons. The maximum Hangul density (9.02±0.14 SE/sq. km) was recorded in winter, and the minimum Hangul density (0.71±0.05 SE/sq. km) was recorded in summer.

The survey results also indicated wide fluctuations in overall Hangul group size and composition between the seasons. The group size varied from 55 individuals in spring and 40 individuals in winter to 1 individual in the summer. The overall Hangul mean group size varied between seasons, with the largest in spring (95% confidence limit 5.36 ±1.28

(*c.* l)) followed by (4.86 ±0.99 *c.* l) in winter. The smallest Hangul mean group size of 1.10 ±0.33 *c.* l. was recorded in summer. The overall typical Hangul group size was 14.11 individuals, and it varied between the seasons from 17.50 individuals in spring to 5.28 individuals in summer. The overall Hangul group composition was 4.30 male, 7.52 female and 5.20 young, and it varied between seasons. As with the Red Deer, the Hangul showed wide sexual segregation. Out of 326 Hangul sightings recorded, Hangul males occurred singly (17% sightings), or in groups of their own, whereas in 18.46% of the sightings, the Hangul groups comprised females only. In 29.54% of the sightings, the Hangul was found in groups of females and fawns. The overall Hangul sex ratio was 23.23 males per 100 females (SE=2.60) and 29.95 young per 100 females (SE=1.90). The overall fawn-to-female ratio was 29.95±1.90 (SE) young/100 females. The Hangul population in Dachigam NP shows a 7.9% increase in growth rate (r=0.079 SD; (r)=0.129); the population will increase to 291.74 Hangul SE=1.51) and stabilise by the 20th year, given that the carrying capacity of the habitat is 300 and there is a low level of poaching (5%). The sensitivity analysis indicated that there is a 25% chance of extinction in 100 years. The population analysis indicates a decrease in genetic heterozygosity over time.

Outside Dachigam NP, the Surfrao/Akhal blocks of Sindh Forest Division, north and north-east of Dachigam NP, Shikargah and Khiram conservation reserves and Overa-Aru WS, to the east and south-east of Dachigam NP, were observed to support a considerable relic population of the Hangul.

DISCUSSION

The current trend of the Hangul population indicates that the species could go extinct if serious management and conservation interventions are not made immediately. Our studies and survey observations indicate that some of the major issues concerning the decline in the population and long term conservation and survival of the Hangul are the highly skewed female biased sex ratio and very low fawn-to-female ratio, predation by Leopard, poaching to some extent and summer dispersal of the Hangul to unknown unprotected areas in the north-west of Sindh Forest Division, outside Dachigam NP, besides some biotic interference by livestock grazers (Iqbal *et al.* 2004; Qureshi and Shah 2004; Ahmad 2006; Ahmad and Khan 2007).

The study results indicate that the social structure, distribution and movement patterns of the Hangul in Dachigam NP are closely associated with the season, topography and changing vegetation and biotic interference patterns over the seasons. In the later half of winter and early spring, i.e., between February and May, there is fresh growth of grasses, herbs, sedges and dwarf shrubs, and flowering of trees, resulting in the downward movement of Hangul from higher to lower elevations and congregation in the ravines, as the mountain peaks surrounding the Park remain under snow cover. In contrast, in summer, the Hangul remains dispersed at higher altitudes moving even outside the Park. This is evidenced by the far fewer Hangul sightings and encounter rates during summer. The deciduous forest conditions, together with the fresh forage, probably improved the visibility of and favoured the sighting of comparatively large group sizes in springs and winter compared to summer and autumn, when the shrub and tree canopy cover impaired animal sightings in Dachigam.

The occurrence of the Hangul in Overa-Aru WS presents an excellent opportunity for a comparative study of its population with that of Dachigam NP. Such a study can throw light on the possible interaction between the two populations. Furthermore, Overa-Aru WS, together with Shikargah/Khiram Conservation Reserve, with which it shares a boundary (Fig. 1), similar to Dachigam NP in topography, climate, and vegetation, can prove to be a suitable habitat for a second viable population of the Hangul outside Dachigam NP. In the past as well, the largest population of Hangul outside Dachigam NP was believed to be supported by the Overa-Lidder forests (Inayatullah 1987). However, the latest census, conducted in March 2000 by the Department of Wildlife Protection, indicates that the Hangul population within and around Overa-Aru WS is 37, which include 12 males, 20 females and 5 fawns. This gives the Sanctuary added importance and calls for special efforts towards the conservation and management of its habitats and wildlife therein. Except for the annual census, conducted by the department, there has hardly been any efforts so far to ascertain scientifically the actual size of the Hangul population of Overa-Aru. As such, information regarding the herd composition sex ratio and home range of the Overa Hangul is lacking. Overa-Aru WS and Sindh Forest Division, falling in the distributional range of the Hangul, are closely linked with Dachigam NP through forest corridors which show a strong vegetational contrast with Dachigam NP as they have been subjected to various types of biotic interferences. With the exception of some steep slopes, the natural vegetation has been replaced in these forest corridors in the valley by cultivated plants along roadsides, and stream sides, and in orchards (Kurt 1979a,b).

In Gurez, some isolated Hangul have also been found to occur. This population might possibly be the only resident western population of Hangul in its erstwhile distribution range. However, this needs to be verified. This area could as

well serve as an ideal habitat for the reintroduction of more Hangul.

The livestock grazing and biotic interferences seemed to show some significantly positive impacts on the movement patterns of Hangul in Dachigam NP. Block 5 of Dachigam NP, in which average livestock dung densities of 25.40 ±17.67/sq. km of cattle and 132.77 ±92.83/sq. km of sheep/goat were recorded during the grazing season (summer-autumn) was used less frequently by Hangul during this period compared with the very frequent sightings in the same block in the non-grazing season (winter-spring). The Hangul encounter rates during summer were lowest in Block 5 (N=2). The Hangul encounter rates, however, increased in this block in late autumn (N=35) and winter (N=180). This block, having its upper reaches above 3,000 m, connected to the subalpine and alpine meadows of Upper Dachigam, experiences heavy livestock grazing and biotic disturbances in summer and a downward migration of grazers during autumn. This possibly forces the Hangul to restrict its movements to away from these two blocks.

Similar patterns have been reported in the displacement and dispersion of Elk and Red Deer away from the areas used by livestock in summer (Dalke *et al.* 1965; Mackie 1970; Lonner 1977; Franklin and Lieb 1979; Skovlin and Vavra 1979; Clutton-Brock *et al.* 1982; Clutton-Brock and Albon 1989). As the densities of livestock increased, the effects on Elk and Red Deer increased. The Sambar has also been found to avoid areas which are used by livestock and pastoral settlements (Sathyakumar 1994; Khan 1995). Long term scientific studies and monitoring of the impacts of grazing and habitat degradation on Hangul should continue in the area through the establishment of 3 to 5 exclosures of dimensions 50 × 50 m in both Lower and Upper Dachigam.

Both direct and indirect evidence suggest that the Surfrao, Akhal and Kangan blocks of Sindh Forest Division attract large populations of Hangul particularly in summer and the beginning of autumn. This might possibly be because the subalpine and alpine meadows of Dagwan, Nagaberan and Marsar of the upper reaches of Dachigam NP, where Hangul used to range in the past (Schaller 1969; Holloway 1971; Kurt 1978) during this season, have been under heavy pressure from biotic interference in the form of excessive livestock grazing by local people, the Gujjar and Bakerwal, and sheep and goats of the Government Sheep Breeding Farm, resulting in the disappearance and displacement of the Hangul from these areas, with the exception of few strays. Significant efforts (30 surveys; 150 hours spent and 300 km walked each in summer and autumn) were expended to assess these subalpine and alpine meadows of Upper Dachigam only during summer and autumn as they were inaccessible during winter and spring due to heavy snow cover. But no direct sightings or indirect evidence of Hangul were obtained in these meadows of Dagwan, Nagaberan and Marsar of Upper Dachigam (Dagwan, Nagaberan and Marsar of the upper reaches of Dachigam NP). Secondly, since most of the drainages (*Nullahs*) in Dachigam NP were observed to be dried up throughout the year, probably due to the impact of global warming, since the glacial areas of Upper Dachigam have been observed to be snowless even during the beginning of summer. The non-availability of water in the near vicinity might have forced the Hangul, especially lactating females in summer, to move towards the disturbed habitats in and outside Dachigam. This might as well be acting as one of the factors for fawn mortality to predators or even sheep dogs. This, however, needs to be scientifically assessed: in one incident, out of a group of 5 or 6 Hangul that were observed crossing a river in Kangan Block of Sindh Forest Division, only 3 animals could be rescued, whereas others fell in the river and died. Initiation of a GPS-satellite telemetry study can help track the movement patterns of Hangul outside Dachigam NP, and in demarcating the actual area on either side of Dachigam used by Hangul that could be declared as a sanctuary to serve as a summer home for them.

The very low Hangul sex ratio is of great concern for the long term survival of the Hangul population. The sex ratio of the Hangul population based on our 2006 extensive survey observations in Dachigam NP and adjoining areas was 21 (SE=2.07) males per 100 females. In 2004, it was observed to be 19 (SE=1.33) males per 100 females, with no significant difference between 2004 and 2006 (t=-0.96, p=0.37). The fawn-to-female ratio seems to be worrying as it shows a significant decline (t=3.4, p=0.01), to 9 (SE = 2.11) fawns per 100 females in 2006 from 23 (SE=2.93) fawns per 100 females in 2004. Our intensive monitoring and observations in Dachigam NP alone, based on all the 326 Hangul sightings made with binoculars, so as to avoid any visibility bias, revealed a female biased overall sex ratio of 23.23 males per 100 females (SE=2.60) and 29.95 young per 100 females (SE=1.90). This observed Hangul sex ratio is lower than the reported ideal sex ratio of 50 to 66.66 males/100 females for Red Deer (Darling 1937; Whitehead 1972; Bonenfant *et al.* 2004). The Hangul sex ratio has never been at such low levels in the past. The Hangul sex ratio in the past is reported to have ranged from 25 to 30 males per 100 females (Holloway 1971; Stockley 1936; Inayatullah 1987).

The very low sex ratio and fawn-to-female ratio could be attributed to significant predation by Leopard on all sex and age classes of Hangul and of Black Bear principally on young deer. Our studies on predator-prey relationships at

Dachigam NP have revealed that the Leopard *Panthera pardus* and the Asiatic Black Bear *Ursus thibetanus* are the major predators in the area and that the Hangul formed a major proportion (about 25%) of the Leopard diet at Dachigam NP (Iqbal *et al.* 2004; Ahmad 2006). In other words, 60% of the biomass of the Leopard diet is constituted by Hangul. This is, however, a grey area of information, and it needs more research. There is a possibility of Hangul predation by other predators such as the Himalayan Yellow-throated Marten *Martes flavigula* in the area which need to be explored. The information obtained by research on the species, particularly on the breeding biology and movement patterns, is still inadequate, and a regulated monitoring of the Hangul populations on a long term scientific basis, particularly during the fawning season and at the time of rut, will help determine the causes of low reproduction and fawn survival in Dachigam and other range areas of the Hangul.

The supplementary food that is being provided to the Hangul in the form of salt and willow leaves at certain fixed spots alone has resulted in habituating Hangul movements around these particular spots. The provisioning of supplementary food in winter is reported to be useful for both male and female deer, preventing greater winter male mortalities in the Red Deer and Elk (Clutton-Brock and Albon 1989; Smith 2001). The same is recommended to be distributed evenly along the main *nullahs* so as to ensure the availability of food and minerals to the Hangul in its distributional areas in Dachigam with minimal efforts during severe weather conditions in winter and spring. The tall grassland and scrub habitats of Dachigam have been used by Hangul as shelters, sources of foraging substrates and as places in which to escape from predators. Their loss due to frequently observed wildfires may represent a significant change in the suitability of these habitats for Hangul use. The establishment of fire lines using the plantation of fire-proof *hatab* (*Parrotiopsis jacquemontiana*) trees to provide natural fire lines in the forests and grasslands of Dachigam may be tried to control fires in the grassland and scrub habitats of Dachigam NP. Controlled and scientific fire management is a tool that will help conserve these pristine Hangul habitats.

An increase in the Hangul population of Dachigam, modelled on the basis of population characteristics reported and studied (2001-2008) for the Hangul and other closely allied subspecies, particularly Red Deer, with a growth rate of 7.9% (r=0.079 SD, (r)=0.129) is indicated. The population will increase to 292 Hangul (SE=1.51) and stabilise by the 20th year, given that carrying capacity of habitat is 300 and there is a low level of poaching (5%). The growth rate without carrying capacity i.e. the growth rate of Hangul without specifying any carrying capacity limits for its growth in Dachigam, would be -8.7% (r=-0.087; SD, (r)=0. 137). The sensitivity analysis indicates a 25% chance of extinction in 100 years. The population will have a decrease in genetic heterozygosity over time. The probability of extinction (PE) for the Hangul population without (normal) and with a density dependent recruitment (den-dep-rec) population ranges between 3% and 4% in a scenario having 5 individuals (2 females and 3 males). Increasing the chance of poaching to 39% (cat-poach and cat-poach - woutdd) with additional winter mortality with a 5% chance of occurrence will substantially increase the extinction risk (cat-poach-winter and cat-poach-winter-woutdd) to 90%. The Hangul population needs an intensive monitoring programme to understand better the factors affecting the population growth.

Since the demographically and genetically viable population of Hangul is presently confined to the 41 sq. km area of the lower reaches of Dachigam NP, it is important to expand the range and habitat of the population to the 141 sq. km extent of Dachigam NP, including the alpine meadows of Upper Dachigam, by taking strict measures to make this area free of livestock grazing so that these ideal summer habitats recover and are used by Hangul in summer as it used to be in the past (Gee 1965; Schaller 1969; Iqbal 1986; Rahul Kaul pers. comm. in 2006). Livestock grazing in Upper Dachigam may prove harmful to Hangul in the long run. Apart from competition for food resources (Smith and Julander 1953), chances of transmission of disease also exist as there has been confirmed evidence of transmission of John's Disease to Hangul in Dachigam in 1978 (Inayatullah 1987). Parasitic investigations of 41 Hangul dung samples from Dachigam NP indicated considerable parasitic infestations of (25%) in the free ranging Hangul population. Recent research studies conducted in the Valley of Flowers NP (Kala *et al.* 1997) and Nanda Devi NP and Kedarnath Wildlife Sanctuary (Sathyakumar 1993, 1994, 2004) have shown that in livestock excluded areas the wildlife habitats have recovered extremely well and that populations of flora and fauna have increased.

A Hangul Species Recovery Plan is required to be initiated urgently. It should include field surveys to identify corridors to help the dispersal of the Hangul to its former distribution range and habitat protection in Upper Dachigam and other potential Hangul habitats outside Dachigam besides a conservation breeding plan for the Hangul to repopulate existing good habitats in the Hangul range. Overa WS and Shikargah Conservation Reserve, almost free from human interference at present, would be ideal locations to initiate Hangul reintroduction. These regions held a good population of Hangul in the past and do hold some stray animals (*c.* 6 individuals estimated in Overa and 7-12 in Shikargah)

today. Besides, these protected areas have diverse and ideal habitats similar to those of Dachigam and close corridor links with Dachigam NP. With the minimum of 10 Hangul which would be required for restocking in an area such as Overa WS, with an assumed carrying capacity of 100 Hangul, and supplementation of 4 more Hangul (2 males and 2 females, each 2 years old), there is a likelihood that the Hangul population will show a growth rate of 5.3% (r=0.053 SD, (r)=0.14) and the population will grow to 88 Hangul in the next 100 years in Overa WS.

However, the other areas of the Hangul's past distribution, such as the Erin catchments of Bandipora, Baltal-Thajwas WS, Tral Reserve, Desu *rakh*, Rajparyan (Daksum) WS and Kishtwar High Altitude NP, require special attention and immediate management and conservation efforts on scientific lines. Continued monitoring and surveys are required to be carried out in these areas for collecting baseline information on the habitat conditions and biotic interference in these areas *vis-à-vis* the present status and distribution of the Hangul, if any. These data could then be interpolated to assess the re-establishment of these areas as well as corridors for Hangul and reintroduction.

Continued examination of the perceptions and the opinions of the local people living near Dachigam NP and adjoining reserves and erstwhile stronghold areas of the Hangul are necessary for perpetuating an effective long term strategy and a conservation and management recovery plan for the Hangul and its habitats, including an *ex situ* conservation breeding programme.

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REFERENCES

AHMAD, K. (2006): Aspects of Ecology of Hangul (*Cervus elaphus hanglu*) in Dachigam National Park, Kashmir, India. Ph.D. thesis, Forest Research Institute, Dehradun, Uttaranchal, India. 220 pp.

AHMAD, K. & JAMAL A. KHAN (2007): Long Term Conservation Plan for Hangul (*Cervus elaphus hanglu*). Final project report, Ministry of Environment & Forests (Wildlife Division), Government of India, New Delhi.

AKCAKAYA, H.R. (2000a): Viability analyses with habitat-based metapopulation models. *Population Ecology 42*: 45-53.

AKCAKAYA, H.R. (2000b): Population viability analyses with demographically and spatially structured models. *Ecological Bulletins 48*: 23-38.

ALTMANN, M. (1952): Social Behaviour of Elk (*Cervus canadensis nelsoni*) in the Jackson Hole area of Wyoming. *Behavior 4(2)*: 116-143.

BHAT, G.A. (1985): Biological studies of grassland of Dachigam National Park, Kashmir. Ph.D. thesis, CORD, University of Kashmir, Srinagar.

BONENFANT, CHRISTOPHE, JEAN-MICHEL GAILLARD, FRANCOIS KLEIN & DANIEL MAILLARD (2004): Variation in harem size of red deer (*Cervus elaphus* L.): the effects of adult sex ratio and age-structure. *Journal of Zoology 264(1)*: 77-85.

BURNHAM, K.P., D.R. ANDERSON & J.L. LAAKE (1980): Estimation of density from line transects sampling of biological populations. *Wildlife Monographs 72*.

CAUGHLEY, G. (1970): Eruption of ungulate populations, with emphasis on Himalayan Tahr in New Zealand. *Ecology 51(1)*: 53-72.

CAUGHLEY G. (1994): Directions in conservation biology. *Journal of Animal Ecology 63*: 215-224.

CHAMPION, H.G. & S.K. SETH (1968): A Review Survey of the Forest Types of India. Government of India Publication, Delhi. 404 pp.

CLUTTON-BROCK, T.H., F.E. GUINNESS & S.D. ALBON (1982): Red Deer: Behavior and Ecology of Two Sexes. Wildlife Behavior and Ecology. Edinburgh University Press, Edinburgh.

CLUTTON-BROCK, T.H. & S.D. ALBON (1989): Red Deer in the Highlands. B.S.P. Professional Books, Oxford and London.

CORBET, G.B. (1978): The Mammals of the Palearctic Region: A Taxonomic Review. British Museum, London.

DALKE, PAUL D., ROBERT D. BEEMAN, FREDERIC J. KINDEL, ROBERT J. ROBEL & THOMAS R. WILLIAMS (1965): Seasonal movements of elk in the Selway river drainage, Idaho. *Journal of Wildlife Management 29(2)*: 333-338.

DARLING, F. (1937): A Herd of Red Deer. Oxford University Press, London.

ELLERMAN, J.R. & T.C.S. MORRISON-SCOTT (1951): Checklist of Palearctic and Indian Mammals. British Museum, London.

FLEROV, K.K. (1952): Fauna of USSR: Mammals. Vol. 1(2). Musk Deer and Deer. *Acad. Sci. USSR New Ser.* no. 55. iii + 257.

FRANKLIN, W.I. & J.W. LIEB (1979): The social organization of a sedentary population of North American Elk: a model for understanding other populations. Pp. 185-198. *In*: Boyce, M.S. & I. D. Hayden-Wing (Eds): North American Elk: Ecology, Behavior and Management. University of Wyoming.

GEE, E.P. (1965): Report on the status of the Kashmir Stag: October 1965. *J. Bombay Nat. Hist.Soc. 62(3)*: 379-393.

GEE, E.P. (1966). Report on the status of the Kashmir Stag: October 1965. *J. Bombay Nat. Hist.Soc. 62(3)*: 1-15.

GEIST, V. (1998): Deer of the World: Their Evolution, Behaviour and Ecology. Stakepole Books, Mechanicsburg, Pennsylvania, U.S.A.

GRZIMEK, B. (1990): Encyclopedia of Mammals. Vol. 5 (Artiodactyla). McGraw Hill Publishing Company.

GROVES, C.P. & P. GRUBB (1987): Relationships of living deer. Pp. 21-59. *In*: Wemmer, C.M. (Ed.): Biology and Management of the Cervidae.

HOLLOWAY, C.W. (1971): The Hangul in Dachigam: a census. *Oryx 10(6)*: 373-382.

HOLLOWAY, C.W. & A.R. WANI (1970): Management Plan for Dachigam Sanctuary. 1971-75. Cyclostyled (mimeo). 26 pp.

HOLLOWAY, C.W. & G.B. SCHALLER (1970): Status and Management of the Hangul. IUCN 11th Technical Meeting, Proceedings. IUCN Pub. New Series. 19(3).

INAYATULLAH, M. (1987): The project "hangul" (*Cervus elephus hanglu*), deer, conservation, India. Pp. 164-173. *In*: Saharia, V.B. (Ed.): Wildlife in India. Natraj Publishers, Dehradun. 278 pp.

IQBAL, M. (1986): Hangul in Dachigam National Park. M.Phil. thesis, University of Kashmir, Srinagar.

IQBAL, S., S. SATHYAKUMAR & Q. QURESHI (2004): Predator-Prey Relationship with Special Reference to Hangul (*Cervus elaphus hanglu*) in Dachigam National Park, Kashmir. Final Project Report. J&K Wildlife Protection Department and Wildlife Institute of India, Dehradun.

IUCN (2006): The IUCN Species Survival Commission - 2006 IUCN Red List of Threatened Species. <http://www.iucnredlist.org>.

JARMAN, P.J. (1974): The Social Organisation of Antelope in Relation to their Ecology. *Behaviour 48*: 215-67.

JHALA, Y.V., Q. QURESHI & R. GOPAL (2005): Monitoring Tigers, Copredators, prey and their habitat. Second ed., rev. Technical Publication of Project Tiger Directorate, New Delhi and Wildlife Institute of India, Dehradun.

KALA, C.P., G.S. RAWAT & U.K. UNIYAL (1997): Ecology and Conservation of the Valley of Flowers National Park, Garhwal Himalayas. Wildlife Institute of India, Dehradun. 99 pp.

KHAN, J.A. (1995): Conservation and management of Gir Lion Sanctuary and National Park, Gujarat, India. *Biological Conservation 73(3)*: 183-188.

KURT, F. (1978): Kashmir Deer (*Cervus elaphus hanglu*) in Dachigam. Pp. 87-109. *In*: Scott, Peter: Threatened deer. Int. Union Conserv. Nat. Nat. Resour (IUCN), Morges, Switzerland.

KURT, F. (1979a): Study Plan for IUCN/WWF Project No. 1103(22-4). Hangul, India: Ecological Study to Identify Conservation Needs. Mimeo. 35 pp 1v.: ill. maps.

KURT, F. (1979b): Study Plan for Hangul [Stag], India: Ecological Study to Identify Conservation Needs. IUCN and WWF, Morges, Switzerland. Unpublished draft final report. 24 pp.

LACY, R.C. (2000): Structure of the VORTEX Similation Model for Population Viability Analysis. *Ecological Bulletin. 48.*

LONNER, T.N. (1977): Statewide Wildlife Research: Long Term Creek Study. Project No. Mont. W-120-r-09/wk.pl.31/job 02/b. Montana Department of Fish and Game, USA.

LOWE, V.P.W. & A.S. GARDINER (1974): A re-examination of the subspecies of Red deer (*Cervus elaphus*) with particular reference to the stocks in Britain. *Journal of Zoology 174(2)*: 185-201.

LYDEKKER, R. (1915): Catalogue of Ungulate Mammals. Vol. 4. Trustees of the British Museum, London.

LYDEKKER, R. (1924): The Game Animals of India, Burma, Malaya and Tibet. Rowland Ward, London. 412 pp.

LYDEKKER, R. (1876): Notes on the geology of Kashmir, Kishtwar and Pangi. *Records of the Geological Survey of India 11(1)*: 30-64.

MACKIE, R.J. (1970): Range ecology and relations of Mule Deer, Elk, and cattle in the Missouri river breaks, Montana. *Wildlife Monographs 20.*

MISHRA, K.D. (1986): Kashmir stag or hangul (*Cervus elaphus hanglu*). Pp. 525-527. *In*: Majupuria, T.C. (Ed): Wildlife Wealth of India: Resources & Management.

NORRIS M.J. (1990): SPSS/PC+ Statistics 4.0 for IBM PC/XT/AT and PS/2 SPSS. International Br. The Netherlands.

OZA, G.M. (1977): Habitat and food of the Kashmir deer or hangul. *Environmental Conservation 4(2)*: 149-150.

QURESHI, Q. & N. SHAH (2004): Population Estimation and Monitoring Protocol for Hangul in Central and South Division of Kashmir. Department of Wildlife Protection, J & K and Wildlife Institute of India, Dehradun.

RODGERS, W.A. & H.S. PANWAR (1988): Planning a Wildlife Protected Area Network in India. Vol. I. Wildlife Institute of India, Dehradun.

RUTLEDGE, R.D. (1982): The method of bounded counts: When does it work? *J. Wldl. Mgmt. 46(3)*: 757-761.

SATHYAKUMAR, S. (1993): Conservation status of mammals in Nanda Devi National Park. Pp. 5-15. *In*: Scientific and Ecological Expedition to Nanda Devi.- A Report. Ministry of Environment and Forests.

SATHYAKUMAR, S. (1994): Habitat Ecology of Major Ungulates in Kedarnath Musk Deer Sanctuary, Western Himalaya. Ph.D. thesis, Saurashtra University, Rajkot. 242 pp.

SATHYAKUMAR, S., S.N. PRASAD, G.S. RAWAT & A.J.T. JOHNSINGH (1994): Conservation status of Himalayan Musk Deer and Live stock Impacts in Kedarnath Wildlife Sanctuary, Western Himalaya. Pp. 240-245. *In*: Pangtey, Y.S.R. & R.S. Rawat (Eds): High Altitudes of the Himalaya: Biogeography, Ecology and Conservation. Gyanodaya Prakashan Nanital.

SATHYAKUMAR, S. (2004): Conservation status of mammals and birds in Nanda Devi National Park: an assessment of changes over two decades. Pp. 1-14. *In*: Biodiversity monitoring expedition: Nanda Devi 2003. A report to Ministry of Environment and Forests, Government of India, Uttaranchal State Forest Department, Dehradun.

SCHALLER, G.B. (1969): Observation on Hangul or Kashmir Stag (*Cervus elephus hanglu*). *J. Bombay Nat. Hist. Soc. 66(1)*: 1-7.

SCHALLER, G.B. (1977): Mountain Monarchs: Wild Sheep and Goats of the Himalaya. Macmillan and Co. Ltd., New York. University of Chicago Press, Chicago. 425 pp.

SHAH, G.M., A.R. YOUSUF & M.Y. QADRI (1984): Winter Diets of Hangul (*Cervus elaphus hanglu*) in Dachigam National Park.

SINGH, G. & P. KACHROO (1978): Plant community characteristics in Dachigam Sanctuary, Kashmir. Natraj Publications, Dehradun.

SIMON, N. (1966): Mammalia. IUCN Red data Book, Vol. I.

SMITH, BRUCE L. (2001): Winter feeding of Elk in western North America. *Journal of Wildlife Management J. Wldl. Mgmt. 65(2)*: 173-190.

SMITH, J.G. & O. JULANDER (1953): Deer and sheep competition in Utah. *Journal of Wildlife Management J. Wldl. Mgmt. 17(2)*: 101-102.

SKOVLIN. J. & M. VAVRA (1979): Winter diets of Elk and deer in the Blue Mountains, Oregon. *USDA For. Serv. Research Paper* PNW; 260, 21 pp.

SPSS (1990): SPSS for Windows: Professional Statistics, Release 10.0. SPSS Inc. Chicago, USA.

STOCKLEY, C.H. (1936): Stalking in the Himalayas and Northern India. Herbert Jenkins Ltd., London.

TALBOT, L.M. (1959): A Look at Threatened Species. Fauna Preservation Society, London.

WADIA, D.N. (1961): Geology of India (3rd edn). Macmillan and Co. Ltd., New York.

WARD, A.E. (1921): Big game shooting of Kashmir and adjacent hill provinces. *J.Bombay Nat. Hist. Soc. 28(1)*: 45-49.

WHITEHEAD, G. KENNETH (1972): The Red Deer of Europe and North Asia. Pp. 68-101. *In*: Deer of the World. Constable and Company Ltd., London.

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WHEN *CHANOS CHANOS* BECAME *TSUNAMI MACCHI*: THE POST-DECEMBER 2004 SCENARIO IN THE ANDAMAN & NICOBAR ISLANDS

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The earthquake that triggered the tsunami of December 26, 2004, also caused a significant and permanent shift of the lay of the Andaman and Nicobar Islands. The northern Andaman Islands saw a lift of up to 1.5 m, while the Nicobars, in the south, subsided in places by nearly 4.75 m. This resulted in much larger damage caused by the tsunami to life and property in the Nicobar Islands even though the area and population here are much less than those in the Andamans. Huge changes were also effected to the topography of the islands and the coastal and marine ecosystems.

An intriguing set of subsequent and successive changes in the disturbed ecosystems have also started to occur, but little is being done to study or understand these. These changes, as also the continued seismic activity in the region, are important determinants that need to be kept in mind for reconstruction and rehabilitation efforts, and for future policy and development planning in these islands.

Key words: Andaman & Nicobar Islands, earthquake, tsunami, December 26, 2004, ecological changes

INTRODUCTION

The Andaman and Nicobar Islands are a chain of 572 islands, reefs and rocks in the Bay of Bengal. The total distance between the extremities is about 355 km, whereas the maximum width is 60 km. The islands are the summits of a submarine range of hills 1,120 km long that connect the Arakan Yoma of Myanmar with the Achin head of Sumatra (Anon 2003). The total area of the island chain is 8,249 sq. km[1] of which the larger and more numerous Andaman group of islands cover 6,408 sq. km, while the southern group of the Nicobars cover 1,841 sq. km (Saldanha 1989).

According to the census data, the total population of the Andaman and Nicobar Islands was 3,56,152 in 2001. Of this the population of the Andaman islands was 3,14,084 and that of the Nicobars was 42,068[2].

The Earthquake and Tsunami of December 26, 2004

The earthquake of December 26, 2004, and the tsunami that came in its wake are the greatest disaster to have hit the Andaman and Nicobar Islands in living memory (Malik and Murthy 2005). This is not surprising considering the fact that Indira Point, the southern most tip of the islands, located on Great Nicobar Island (6° 45.2' N; 93° 49.6' E), is only about 180 km from the epicentre of the earthquake that triggered the tsunami. Official figures list 3,513 people as either dead or missing and 7,992 hectares[3] as the paddy and plantation land that was affected. A total of 938 boats were fully damaged, while the number of livestock reported to have been lost in the disaster is 1,57,577 (Anon 2006; Chandi n.d.).

Disaggregation of these figures along the lines of the two island groups gives a very interesting and important picture. Of the 3,513 people reported dead and missing, only 64 are from the Andaman group of islands, the remaining 3,449 being from various islands in the Nicobar group. Of the total agricultural and paddy land destroyed, 76% is from the Nicobar group. Similarly, 80% of livestock loss was in the Nicobars. The latest figures for houses being constructed for the tsunami affected also indicate a similar trend. Of the 9,797 permanent houses being constructed, 7,001, or 71%, are in the Nicobars (Table 1).

It is evident that the impact in the Nicobar group of islands was much worse than that in the Andaman Islands. So, while the Nicobar Islands account for only 22% and 12% of the area and population, respectively, of the entire chain of islands, 98% of the deaths and 76% of loss of agricultural land occurred here. The damage caused is inversely proportional to the area and population of the two groups and strikingly so (Table 2).

While the tsunami was directly responsible for most of the damage, a more fundamental explanation lies in the earthquake that caused the tsunami. While the tectonic movements triggered by the earthquake catalysed the tsunami, they also caused a huge and permanent shift in the lay of the

[1] It is important to bear in mind that these are pre-December 2004 figures. The latest figures are not available.

[2] The estimated total population for the island group in 2009 was 475,000.

[3]A subsequent statistic from the A&N administration indicates that the total agricultural land lost was 10,837 hectares, of which 9,107 hectares was said to be plantation land and 1,730 hectares was paddy land. The island-wise break-up for this figure is not available.

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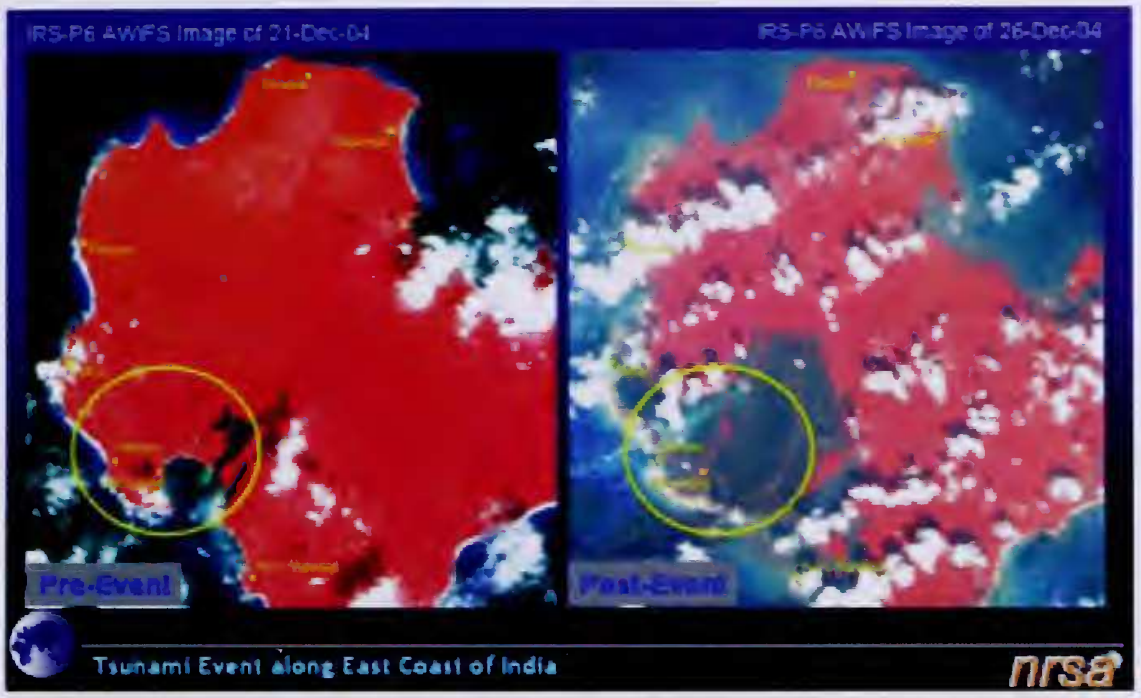

Fig. 1: Satellite images of Katchall island before (left) and after (right) the earthquake of December-2004

Table 1: Island-wise losses

	People (dead or missing)		Livestock loss		Agricultural land lost		Permanent housing		Area		Population (2001)	
	Total number	%	Total number	%	Area in hectares	%	Number	%	Sq. km	%	Number	%
Andamans	**64**	**2**	**31,521**	**20**	**1,877**	**23.5**	**2,796**	**28.6**	**6,408**	**77.68**	**3,14,084**	**88**
South Andaman			19,634		1667		823					
Little Andaman			11,165		117		1,973					
Middle Andaman			722		93							
Nicobars	**3,449**	**98**	**1,26,056**	**80**	**6,115**	**76.5**	**7,001**	**71.4**	**1841**	**22.32**	**42,068**	**12**
Car Nicobar	854		50,350		969.35		3,941					
Chowra	117		11,896		230.4		346					
Teressa			17,307		743.96		506					
Katchal	1,551		18,678		1,628.50		315					
Nancowry	378		1,440		256.57		269					
Kamorta			7,501		637.4		518					
Trinket			2,590		328.5							
Little Nicobar			2,267				111					
Great Nicobar	549		12,298		1,291.28		995					
Kondul			336									
Pilomilow			823									
Bambooka			570		29.55							
Total	**3,513**	**100**	**1,57,577**	**100**	**7,992**	**100**	**9,797**	**100**	**8,249**	**100**	**3,56,156**	**100**

Andaman and Nicobar Islands. Preliminary reports and assessments show that with a pivot figuratively and roughly located near Port Blair, the Andaman Islands, in the north, experienced a permanent uplift of 1-2 m, while there was a subsidence of up to 4 m in the Nicobar group of islands (Bilham *et al.* 2005; Malik and Murthy 2005; Ramanamurthy *et al.* 2005; Thakkar and Goyal 2006)[4] (see Web link in reference for map; also see attached maps (Figs 1 and 2) from the

[4]Also see http://cires.colorado.edu/%7ebilham/IndonesiAndaman2004_files/AndamanSRL4Mar.htm and (downloaded 10/08/2010) and http://dsc.nrsc.gov.in:14000/DSC/Tsunami/CaseStudies.jsp?state=ANDAMAN_NICOBAR%20ISLANDS# (downloaded 10/08/2010)

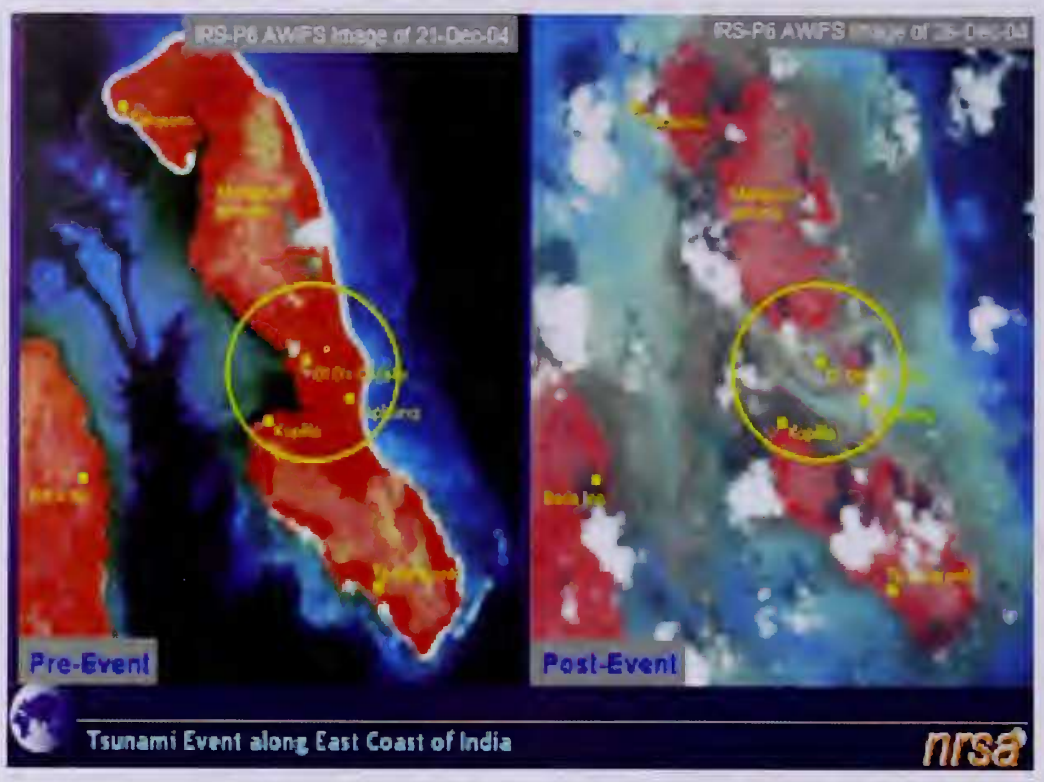

Fig. 2: Satellite images of Trinkat island before (left) and after (right) the earthquake of December-2004

National Remote Sensing Agency (NRSA)). The tide gauge at Port Blair is reported to have recorded an initial subsidence of the harbour (or rise in sea level) about 38 minutes after local shaking commenced (op. cit.). Eyewitness accounts indicate that the main shocks were felt in Port Blair around 0635 hrs IST on December 26, 2004. While this was followed almost immediately (15-20 minutes later) by the first influx of sea waves, it was around 0830 hrs, 2 hours after the main shock, that a third wave hit the shores with a velocity that caught citizens unaware (Anon 2005b).

Other reports (http://www.asce.org/files/pdf/tsunami/3-7.pdf) indicate that there was a gap of 50 minutes between the initial earthquake and the first wave of the tsunami in Port Blair. Three more waves are reported to have followed with a gap between each other of 30-35 minutes. While there is no information to indicate what may have happened in other parts of the islands, it can perhaps be assumed that the pattern everywhere was the same and, by implication of importance and significance, that the subsidence and uplift of the landmass occurred before the most powerful and damaging of the tsunami waves hit the shores of the Andaman and Nicobar Islands. The Nicobars, though spread over a smaller area and also more thinly populated, suffered much greater damage than did the Andamans as a consequence, and this is reflected in the figures of those killed during the tsunami and of agricultural and horticultural land lost.

The dominant human population in the Nicobar Islands is the Nicobari tribal community, which is essentially coastal dwelling (Singh 2006). They were therefore the most

Table 2: Island-wise losses as percentages

	Andamans (%)	Nicobars (%)	Total
Area (sq. km)	6,408 (77.68)	1,841(22.32)	8,249
Population (2001)	3,14,084 (88)	42,068 (12)	3,56,152
People (dead or missing)	64 (2)	3,449 (98)	3,513
Livestock loss	31,521 (20)	1,26,056 (80)	1,57,577
Agricultural land lost (hectares)	1,877 (23.5)	6,115 (76.5)	7,992
Permanent housing	2,796(28.6)	7,001 (71.4)	9,797

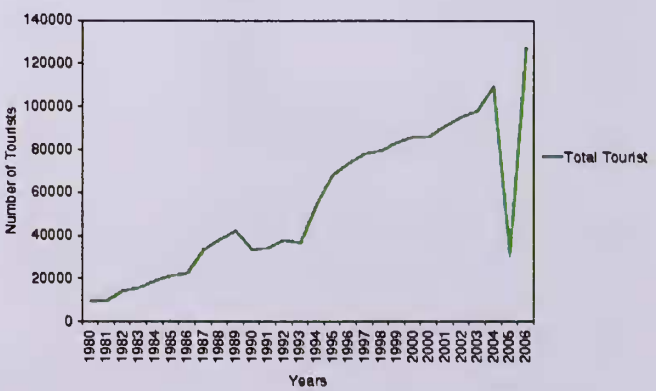

Fig. 3: Tourist arrivals in the Andaman Islands

vulnerable and in the direct route of the powerful tsunami which followed the significant subsidence that took place on account of the earthquake. Of the 3,513 people reported dead or missing, a full 2,955 were from the tribal community (Anon 2006).

ECOLOGICAL CHANGES

The Nicobar Islands

Significant changes were reported along the coastline of most of these islands. The small Megapode Island, located west of Great Nicobar, has, for instance, gone completely under (Manish Chandi, pers. comm.). Coral reefs, beaches and low lying coastal forests across the Nicobars were badly affected. The Nicobar reefs were hit due to the combination of the submergence, the resultant increase in turbidity and the physical damage caused by the tons of debris thrown back and forth by the furious waves. A survey conducted by the Zoological Survey of India reported large scale sedimentation on coral reefs around Great Nicobar Island after the tsunami. A reduction in the number of other associated coral reef fauna including nudibranchs, flat worms, alpheid and mantis shrimps, and hermit and brachyuran crabs was also reported (Alfred *et al.* 2006).

In an interesting development immediately after the tsunami, fishermen from Campbell Bay, in Great Nicobar, reported a sudden and huge increase in the catch of Milk Fish *Chanos chanos*, which was relatively rare earlier. So huge and sustained was the harvest of this particular fish that it quickly came to be called the 'tsunami *macchi*' (Anon 2005a). While the exact causes can only be speculated about, a post-tsunami ocean salinity and temperature study carried out in the islands by scientists of the National Centre for Antarctic and Ocean Research did find a considerable thermohaline variability in the upper 300 m column of ocean water and concluded that changes such as this could be expected to have a significant impact on primary production and fisheries (Luis *et al.* 2007).

Early surveys conducted by the Andaman and Nicobar Environment Team (ANET) in the Nicobars also indicated huge losses of Pandanus *Pandanus leram* and the Nypa Palm *Nypa fructicans*. The Nypa Palm in particular was wiped out almost completely from the estuarine regions of Little Nicobar and Great Nicobar islands. Significantly, both these plants are extremely important for the Nicobari community as a source of food and materials for regular use, such as for thatch for their dwellings. An effort is now being made with the help of the local communities to repopulate these islands with these very important and useful species (Chandi 2005a,b, 2006).

The permanent submergence in the Nicobars also saw the immediate and complete loss of most of the beaches here, many of which were important nesting sites for the 4 marine turtle species found here — the Giant Leatherback *Dermochelys coriacea*, the Green Sea Turtle *Chelonia mydas*, the Olive Ridley *Lepidochelys olivacea* and the Hawksbill *Eretmochelys imbricata*. This change, however, was a short-lived one, and new beaches had started to form along the altered alignment within months. Nesting turtles too were back again very soon (Murugan 2006; Chandi *et al.* 2006).

The damage to the low lying coastal areas, the coastal forests and the mangroves, however, was more permanent. Large tracts of the forests were completely destroyed, and for many months after the disaster the islands in the Nicobars could be seen encircled by an endless brown wall of dying and decaying trees. A remote sensing and GIS based study of the Central Nicobar group of islands (Nancowry, Camorta, Trinket and Katchal) by the Institute for Ocean Management at Chennai's Anna University has assessed the damage to range from 51% to 100% for mangrove ecosystems, 41% to 100% for coral reef ecosystems and 6.5% to 27% for forest ecosystems (Ramachandran *et al.* 2005).

Dr. Ravi Sankaran of the Sálim Ali Centre for Ornithology and Natural History (SACON) conducted a rapid impact assessment of the Nicobars almost immediately after the disaster. His main interest was to look at the status of the Nicobari Megapode *Megapodicus nicobariensis nicobariensis* and *M.n. abbotii*, the ground nesting endemic bird that scrapes together a mound of earth as a nest in low lying coastal forests. The submergence in the Nicobars had permanently destroyed a huge part of the bird's nesting habitat, and the study found that nearly 1,100 nesting mounds had been lost (Sankaran 2005).

A subsequent survey in early 2006 by the Wildlife Institute of India covered nearly 110 km of the coastline in 15 islands in the Nicobar group. The study estimated that only about 500 active nesting mounds of the bird had survived in the Nicobars and that the megapode population post-tsunami was less than 30% of what had been estimated during surveys conducted nearly a decade ago (Sivakumar 2006). While the bird has certainly been hit badly, the impact is not as bad as was initially feared.

Little is known, however, of the other equally vulnerable, coastal forest dwelling fauna, prominently, the Giant Robber Crab *Birgus latro*, the Reticulated Python *Python reticulatus* and the Malayan Box Turtle *Cuora amboinensis*. There is almost no idea of how these have been impacted, and there are indications that these have come worse off than the megapode.

There were initial fears, particularly in the case of the Giant Robber Crab that it might have become locally extinct in the Nicobars as it inhabits that section of the coast that was

most badly devastated – the less than 100 m wide strip of forest adjacent to the sea. There were reports however that they were being occasionally sighted and this was confirmed when four individuals – two on Camorta Island and one each on Great Nicobar and Menchal were sighted in late 2006 (Patankar 2007).

The Andamans

Areas around Port Blair also experienced permanent submergence (about 2-3 feet) and saw a fate similar to that of the Nicobars. The damage is most clearly seen in the low lying area of Sippighat, just a few kilometres outside the capital town. Mangrove marshes that had been converted to paddy fields over many years were permanently submerged and lost. A study conducted by scientists of the Port Blair based Central Agricultural Research Institute (CARI) found a severe impact on mangroves in the creeks of Sippighat, Shoal Bay, Chouldhari and Mahatma Gandhi Marine National Park at Wandoor, due to high salinity stress and permanent inundation (Dam Roy and Krishnan 2005). As in the case of Great Nicobar, this led to one dramatic, though short lived, change here. For the first few months immediately after the tsunami, Sippighat Creek became a huge production ground for the best prawns that residents of Port Blair had ever eaten (pers. obs).

Most of the other parts of Andamans, however, experienced a fate that was the opposite of that of the Nicobars and of what was seen near Port Blair. The CARI study found, for instance, that the mangrove stands of Deshbandhugram, Laxmipur, Milangram and Swarajgram, in North Andaman, remained exposed even during high tide. Sea water was not reaching the mangroves at all, and within a few months of the event they had started to wilt (Dam Roy and Krishnan 2005).

The most dramatic impact, however, was seen off the west coast of the northern part of the Andaman Islands. Huge areas of coral reefs were permanently thrust above the high tide line, destroying them within weeks. A rapid assessment of the Andamans carried out by the Andaman and Nicobar Environmental Team (ANET) 2 months after the earthquake estimated that more than 50 sq. km of coral reefs had been so exposed and killed – the largest area being nearly 25 sq. km, west and north of Interview Island (Andrews and Vaughan 2005). A similar impact was seen in parts of Indonesia too. The coral reef damage due to the tsunami was nominal in comparison to that which happened on account of the earthquake. "The most dramatic damage to Aceh reefs," says a report by Living Oceans, Reef Check and IUCN, "was also caused by the earthquakes. Hectares of reef flat at Pulau Bangkaru Island and Simeulue were uplifted to a level above the high tide mark resulting in total mortality of previously healthy and intact reefs" (Foster *et al.* 2006).

The situation for the sea turtle nesting beaches appears to have turned up a mixed bag in the islands. Flat Island, a small island on the west coast of the main Andamans, for instance, was an important sea turtle nesting site prior to the tsunami. The uplift caused by the earthquake has exposed coral reefs surrounding the island and now created a barrier to sea turtles visiting the island to nest. Some beaches such as those in Little Andaman Island are reported to have become wider, and the gradients have also become gentler due to the tectonic activity (Chandi *et al.* 2006). The ANET team also reported extensive damage to sea grass beds, something that was evident by the many weak Green Sea Turtles and dead specimens that were seen in many places during the surveys they conducted.

CONCLUSION

The islands have always been very active seismically (Rajendran *et al.* 2003), and there is evidence now that the sensitivity and activity have increased since December 2004. Nearly 20 earthquakes of a magnitude over M6 in addition to several hundred of lesser intensity have been recorded in the region after December 2004 (http://earthquake.usgs.gov/regional/world/historical_country.php#indian_ocean).

Some, such as the September 12, 2007, earthquake off the Sumatra coast of a magnitude greater than M8 on the Richter scale resulted in a tsunami warning being issued in the Andaman and Nicobar Islands as well (Raju 2007).

Increased seismic activity and the increased threat on account of this need to now be made an important aspect of policy and development planning in the islands. Similarly, the change in the topography of the islands on account of the tectonic movements caused as a result of the massive earthquake of December 26, 2004, needs to be factored in, both for the ongoing relief and rehabilitation work here and for future planning.

An important illustrative example would be the tourism industry in the islands and its aggressive promotion post-December 2004. The industry has been promoted as an important revenue earner and employment creator for people in the islands. A lot of financial resources are also being spent to encourage tourists to come to the islands, and special packages for government employees have also been created.

A study led by the NGO EQUATIONS (Anon 2008), however, shows that the contribution of the tourism industry to the economy of the islands is extremely nominal. The contribution of tourism in the islands to the Gross State Domestic Product (GSDP) has been stagnant at around 8% for the last 2 decades though tourism arrivals themselves have

grown by about 1,000%. Further, its contribution to revenue generation is also insignificant. Tourism (as in the hotels and restaurants sector) was found to employ less than 1.5% of the total main workforce of the islands, and this employment is seasonal. It is well-known that tourism is an extremely fickle industry and is affected adversely and almost immediately by other factors such as natural disasters, political strife or economic fluctuations. Figures for tourist arrivals (see Fig. 3) to the Andaman Islands provide an excellent indication of this as numbers fell to almost nil immediately after the tsunami. Creating exclusive reliance on such an industry for stimulating economic growth and employment is bound to fail.

There is an urgent need also to re-calibrate the high tide line (HTL) across the islands to allow correct implementation of the regulations related to coastal management and development. This has implications for development planning, location of construction projects, including those for tourism, and ensuring protection of the coast as per the laws and policies of the land.

As far as the ecological changes are concerned, observers (Andrews and Vaughan 2005; Sankaran 2005) have argued that no drastic interventions should be made to "correct" the situation. They have argued that no intervention would be the best intervention and the processes of nature should be allowed to take their own course.

An understanding and incorporation of these aspects should be made fundamental to dealing with the present and future situation in the A&N islands. That would be the first step towards dealing with existing and future vulnerabilities. Ignoring these and the implications is only an invitation to more trouble in the future, with potentially disastrous consequences.

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REFERENCES

ALFRED, J.R.B., R. JEYABASKARAN & D.V. RAO (2006): Impact of tsunami on biodiversity of Andaman and Nicobar Islands. *Envis Newsletter 12(1&2)*: 2-5.

ANDREWS, H.V. & A VAUGHAN (2005): Ecological assessment in the Andaman Islands and observations in the Nicobar Islands. Pp. 78-103. *In*: Kaul, R. & V. Menon (Eds): The Ground Beneath the Waves: Post-tsunami Impact Assessment of Wildlife and their Habitats in India. Vol II. Wildlife Trust of India, New Delhi. 104 pp.

ANON. (2003): Biodiversity Characterisation at Landscape Level in Andaman & Nicobar Islands Using Satellite Remote Sensing and Geographic Information System. Indian Institute of Remote Sensing, Dehradun, Uttarakhand. 304 pp.

ANON. (2005a): 'Potential tiger shrimp ground reported from C/Bay' The Daily Telegrams July 18, 2005: http://in.groups.yahoo.com/group/andamanicobar/message/1413 (accessed 10/08/2010)

ANON. (2005b): A Preliminary Report on Investigation of Effects of the Sumatra-Andaman Earthquake of 26 December 2004 in Andaman and Nicobar Islands. Geological Survey of India, New Delhi.

ANON. (2006): Andaman and Nicobar Islands: Towards a Brighter Tomorrow. A&N Administration, Port Blair.

ANON. (2008): Rethink Tourism in the Andamans: Towards Building a Base for Sustainable Tourism. Research report. EQUATIONS, INTACH — Andaman & Nicobar Islands Chapter, Society for Andaman and Nicobar Ecology, Kalpavriksh, Jamsetji Tata Centre for Disaster Management — Tata Institute of Social Sciences, Action Aid International India. xii+332 pp.

BILHAM, R., E.R. ENGDAHL, N. FELDL & S.P. SATYALBALA (2005): Partial and complete rupture of the Indo-Andaman plate boundary 1847-2004. *Seismological Research Letters 76(3)*: 299-311, http://cires.colorado.edu/%7ebilham/IndonesiAndaman2004_files/AndamanSRL4Mar.htm

CHANDI, M. (n.d.): Name of Tuhet plantation places on Pulomilo Island. Unpublished short note. 2 pp.

CHANDI, M. (2005a): A note on the rehabilitation requirements of the islanders of Little Nicobar, Pulomilow and Kondul of the southern Nicobar Islands. Reefwatch Marine Conservation, Mumbai & Andaman and Nicobar Environment Team, Wandoor, A&N Islands. Unpublished Report. 6 pp.

CHANDI, M. (2005b): Report of a Visit and Survey of Little Nicobar and Great Nicobar Islands from March 13 to 22. Reefwatch Marine Conservation, Mumbai & Andaman and Nicobar Environment Team, Wandoor, A&N Islands. Unpublished Report. 8 pp.

CHANDI, M. (2006): Report on Participatory Regeneration of *Nypa fruiticans*: A Resource Augmentation Program in the Southern Nicobar Islands. ANET report. Madras Crocodile Bank Trust, Mamallapuram. Unpublished Report. 17 pp.

CHANDI, M., SAW PAUNG, SAW AGU, SAW PORICHA, SAW JOHN & ALLAN VAUGHAN (2006): Notes and observations on flora and fauna during a survey of the coastline and sea turtle nesting beaches of the Andaman Islands. Report to the A & N Environmental Team, Wandoor, South Andaman Island. Unpublished Report. 39 pp.

DAM ROY, S. & P. KRISHNAN (2005): Mangrove stands of Andamans *vis-à-vis* tsunami. *Current Science 89(11)*: 1800-1804.

FOSTER, R., A. HAGAN, N. PERERA, C.A. GUNAWAN, I. SILABAN, Y. YAHA, Y. MANUPUTTY, I. HAZAM & G. HODGSON (2006): Tsunami and Earthquake Damage to Coral Reefs of Aceh Foundation. Pacific Palisades, California, USA. 33 pp.

LUIS, A.J., S.M. PEDNEKAR & M. SUDHAKAR (2007): Post-tsunami impact study on thermohaline structure in the Bay of Bengal. *Current Science 93(5)*: 699-703.

MALIK, J.N. & C.V.R. MURTHY (2005): Landscape changes in Andaman and Nicobar Islands (India) due to *Mw* 9.3 tsunamigenic Sumatra earthquake of 26 December 2004. *Current Science 88(9)*: 1384-1386.

MURUGAN, A. (2006): The effect of tsunami on sea turtle nesting beaches along the coast of India. Pp. 75-78. *In*: Proceedings of the 2nd International Symposium on South East Asia Sea Turtle Associative Research (SEASTAR) 2000 and Asian Bio-logging Science. Graduate School of Informatics, Kyoto, Japan

PATANKAR, V. (2007): First post-tsunami sighting of the coconut crab in the Nicobar Islands. *Oryx 41(3)*: 1-2.

RAJENDRAN, C.P., A. EARNEST, K. RAJENDRAN, R. DEV DAS & S. KESAVAN (2003): The 13 September 2002 North Andaman (Diglipur) earthquake: an analysis in the context of regional seismicity. *Current Science 84(7)*: 919-924.

RAJU, G. (2007): Tsunami threat: once bitten twice shy? *The Light of Andamans 17 September 2007*: 3.

RAMACHANDRAN, S., S. ANITHA, V. BALAMURUGAN, K. DHARANIRAJAN, K. EZHIL VENDHAN, MARIE IRENE PREETI DIVIEN, A. SENTHIL VEL, I. SUJJAHAD HUSSAIN & A. UDAYARAJ (2005): Ecological impact of tsunami on Nicobar Islands (Camorta, Katchal, Nancowry and Trinkat). *Current Science 89(1)*: 195-200.

RAMANAMURTHY, M.V., S. SUNDARAMOORTHY, Y. PARI, V. RANGA RAO, P. MISHRA, M. BHAT, T. USHA, R. VENKATESAN & B.R. SUBRAMANIAN (2005): Inundation of sea water in Andaman and Nicobar Islands and parts of Tamil Nadu coast during 2004 Sumatra tsunami. *Current Science 88(11)*: 1736-1740.

SALDANHA, C.J. (1989): Andaman, Nicobar and Lakshadweep: An Environmental Impact Assessment. Oxford and IBH Publishing House, New Delhi. xi+114 pp.

SANKARAN, R. (2005): Impact of the earthquake and the tsunami on the Nicobar Islands. Pp. 10-77. *In*: Kaul, R. & V. Menon (Eds): The Ground Beneath the Waves: Post-tsunami Impact Assessment of Wildlife and Their Habitats in India. Vol II. Wildlife Trust of India, New Delhi. 104 pp.

SINGH, S.S. (2006): The Nicobar Islands: Cultural Choices in the Aftermath of the Tsunami. Oliver Lehmann, Czernin Verlag Vienna, Austria 228 pp

SIVAKUMAR, K. (2006): Wildlife and Tsunami: A Rapid Assessment on the Impact of Tsunami on the Nicobar Megapode and Other Associated Coastal Species in the Nicobar Group of Islands. Wildlife Institute of India, Dehradun. 19 pp.

THAKKAR M.G. & B. GOYAL (2006): Historic submergence and tsunami destruction of Nancowrie, Kamorta, Katchall and Trinket Islands of Nicobar district: consequences of 26 December 2004 Sumatra-Andaman earthquake. *Current Science 90(7)*: 989-994.

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PITFALLS AND OPPORTUNITIES IN THE USE OF MARKET-BASED INCENTIVES FOR BIODIVERSITY CONSERVATION

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Market arrangements fail to capture the range of benefits provided by conservation because of their public goods nature. In consequence, biodiversity is routinely undervalued and overexploited. A variety of instruments and payment schemes have been developed to help finance conservation by capturing these non-marketed benefits. This paper reviews market-based approaches identifying the salient features which determine their potential for improving conservation finance.

Key words: Market-based Instrument, Payment for Ecosystem Services, biodiversity conservation, environmental decision making

INTRODUCTION

Market-based mechanisms have taken a respected position among the tools for achieving both conservation and broader environmental objectives. The title of the reports, "Harnessing Market Forces to Protect the Environment," (Project 88 Conference 1989) and "Harnessing Markets for Biodiversity" (OECD 2001) are suggestive of the expectations placed on the power of market forces to achieve environmental goals. Other titles on the subject, such as "Silver Bullet or Fool's Gold," (Landell-Mills and Porras 2002) suggest that more circumspection is necessary before wholesale acceptance of market-based mechanisms as tools of biodiversity conservation. Market-based mechanisms are based on the market forces of supply, demand and trade. They rely upon price-type signals and trading among agents responding to economic opportunities, such as increased incomes or lower costs. Instruments considered to be "market-based" include:

1. Price-based instruments, such as taxes for undesirable behaviours, such as habitat degradation, pollution or species takes, fees, and penalties;
2. Price-based instruments, such as subsidies, to reward desirable behaviours, such as maintenance of land under forest cover, debt-for-nature swaps and conservation easements;
3. Price-based liability approaches such as deposit-refunds and performance bonds;
4. Quantity-based instruments involving market creation and trading of responsibilities, such as wetland mitigation banks, carbon credits, fishing permits and land development rights;
5. Demand enhancements and information disclosure, such as eco-labelling, and certification.

The first and perhaps most important surrounding the use of market-based incentives is that, from an economic perspective, environmental problems have traditionally been explained as results of market failure or the absence of markets. The market failure perspective poses several questions that are not answered satisfactorily by the conventional economic approach to environmental problems.

- First, when and how is it possible to transform the problem setting under interest so that quasi or real markets can be created where none existed before?
- Second, what economic, distributive and governance advantages or disadvantages do market-based instruments offer in comparison to government-centered regulatory solutions or public supply?
- Thirdly, what is the full range of market-based solutions that are applicable for conservation?
- Fourthly, what are the key issues that determine which market-based solutions can be expected to support conservation?

The purpose of this paper is to address these questions and consider the role that market-based instruments can play in achieving conservation objectives. While there certainly may be opportunities, there are also pitfalls that must be avoided in implementing these instruments for conservation.

1. Market failure versus ecosystem services as the basis of conservation transforming the problem setting

Conventional welfare economics suggests that environmental problems are caused by the absence of markets or by market failures such as externalities, public goods, and

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imperfect information. This public goods element to environmental problems has suffered from consistency problems. Some scholars have defined public goods as goods that are provided publicly, others have underlined the difficulty of excluding unauthorized users as their hallmark, and still others have rightly associated public goods with non-rival or joint consumption. The lack of excludability and rivalry in consumption provides an incentive for consumers to free ride and disincentives to potential providers who are unable to exclude unauthorized users. From an efficiency point of view, this results in too high or low level of an environmental impact or service, and a corresponding suboptimal allocation of environmental resources. Conventional solutions have relied predominantly on command and control measures or the public provision of public goods.

In terms of externalities, conventional theory portrays environmental problems as unwanted side-effects of otherwise beneficial economic activities. It then suggests a narrow range of government-centered policy responses such as regulations, forgetting that government intervention is not always needed to resolve externality problems if agents can bargain with one another (Coase 1960; Cheung 1973). There is evidence that many jointly consumed or high exclusion cost goods have successfully been provided privately (Coase 1974) or communally (Ostrom 1990). Therefore, there may exist alternative working governance solutions which have been overlooked by the dominant policy paradigm.

An alternative framework for addressing environment/economic interactions stems from the view that biodiversity and ecosystem services play a fundamental role in sustaining all human activity, and that well-functioning ecosystems are germane to human welfare. The concept of ecosystem services has its roots in ecology, but many ecological economists have made it a starting point for their economic analysis. Ecosystem services can be defined as "the benefits humans receive, directly or indirectly, from ecosystems" (Costanza *et al.* 1997; Farber *et al.* 2006) or as "the end products of nature that yield human well-being" (Boyd and Banzhaf 2005). Ecosystem services are generated by ecosystem functions, such as regulation, habitat, production and information, which in turn are underpinned by ecosystem structures and processes (de Groot *et al.* 2002).

Ecosystem services are of unquestionable economic relevance. Costanza *et al.* (1997) have estimated that the value of the world's ecosystem services is at least $ 33 trillion annually. Balmford *et al.* (2002) have demonstrated that nature conservation often generates higher economic returns than intensive use of natural systems, which entails their conversion (Turner *et al.* 2003; Naidoo and Adamowicz 2005). A vast amount of more narrowly focused valuation research exists. However, natural systems should not be valued only in terms of the benefit streams they generate. Natural systems provide life support services and have "glue value", because they constitute the infrastructure without which the provision of ecosystem services would not be possible (Turner *et al.* 2003).

Ecosystem services' thinking has undoubtedly broadened possibilities for supporting biodiversity conservation. Ecosystem service approaches are steadily gaining currency in policy spheres with a number of recent governance reforms being either directly underpinned by such an approach or compatible with it. For example, the European Union's Habitats and Water Framework Directives create multi-level governance solutions with jurisdictions that respect spatial aspects of the pertinent resources. These governance solutions also recognise a range of user groups and involve them in planning and decision-making processes. The support of environmental protection measures under the European Common Agricultural Policy (CAP) in turn commissions ecosystem services from private providers. These payments for the provision of ecosystem services are not subsidies: they are prices paid for the provision of services to private providers, who own and control environmental assets such as forests, pastures, or agricultural land.

In recent years, lack of information or information asymmetries between potential market participants has come to seen as a further reason for missing or inefficient markets. For markets to develop in conservation related services, one set of required information is understanding the functioning of ecosystems and ecosystem services, their dependence on land cover or use and metrics for measuring service delivery over baselines. Recognition, and identification, and better scientific understanding of ecosystem services have therefore led to more voluntary, Coasian type bargains, between private parties.

Nestlé, which owns the natural mineral water sources of Vittel in France, protected the spring catchment area, which had been intensively farmed (with resulting nutrient run-off and pesticide residues), by purchasing and reforesting the catchment. It further reduced non-point pollution by signing 18-to-30-year contracts with the local farmers to reduce nitrate pollution (The Economist 2005). In 1998, a hydroelectricity company signed a voluntary agreement to pay a local NGO, the Monteverde Conservation league for the water-based services provided by the forest they own (Reyes *et al.* 2002). In the Philippines, a hydroelectric company also provides incentives to local communities for reforestation of a water catchment (Mero 2002). Conservation easements and land trusts are also examples

of self-organized private deals between organizations and landowners whereby a conservation or protection arrangement is privately negotiated and purchased.

2. What economic, distributive, and governance advantages or disadvantages do market-based instruments offer in comparison to conventional government-centered solutions such as regulation and public supply?

The choice of governance and institutional arrangements in the management or delivery of services affirms or redefines entitlements to environmental resources, and has thus both efficiency and distributive consequences. Choices between different instruments for biodiversity conservation are primarily about the distribution of wealth and income, and about the realization of sought-after conservation outcomes.

Characterizations of environmental policy instruments commonly distinguish between "command and control" measures and "market-based" measures. Command and control measures include a wide range of environmental regulations, binding environmental plans, and procedural requirements.

The common feature of both categories of policy instrument is the creation of entitlements to ecosystems or ecosystem services. Environmental regulations are often viewed purely as constraints but they do create entitlements (albeit non-transferable ones). Regulations that prohibit the use of substances such as DDT, or the taking of an endangered species, create the entitlement to be free from the adverse consequences of these actions. Similarly, the conditions of pollution permits issued under the US's Clean Water Act, vest in the polluter conditioned entitlements to the capacity of water courses to assimilate wastes. Such entitlements are less explicit than in the sphere of market-based instruments where there has been a better understanding of how they create transferable entitlements, which facilitate their exchange.

Conventional wisdom has it that compared to command and control measures, market-based instruments are better at achieving environmental objectives at lower cost to both industry and society. This is due to the ability to transfer responsibilities across parties, as in the case of tradable permits, and the incentives created by some instruments for parties to reduce environmental management costs through introduction of better technologies and practices. Evidence from pollution control programs supports this view. The US Acid Rain program used a trading scheme to reduce emissions of sulphur dioxide. The resulting market was estimated to have resulted in cost savings of $1 billion annually compared to the expected costs under a command and control approach (Stavins 2001). Some have argued that command-and-control regulations are not necessarily worse in this respect and caution against a blanket prescription for market-based approaches (Porter and van Linde 1995). Some authors argue that such approaches are more suited for the institutional context of modern nations, rather than developing countries (Russell and Powell 1996).

The choice of instrument type is often a matter of distributive justice. For example, many agri-environmental schemes recognize transferable entitlements of farmers while industrial polluters are often regulated. The latter often have market power which enables them to share costs of improved environmental protection with their customers by raising prices. Farmers have a far weaker position to do so in the markets for agricultural produce, so are more cost-conscious. Distributive justice is an important issue for conservation of biodiversity in both the developing and developed world. If the costs and benefits conservation accrue unevenly to different groups, those left with the costs are hardly motivated to contribute to conservation.

A disadvantage of market-based instruments is that they are not good in guarding against irreversibilities or dangerous outcomes. It is noteworthy, however, that regulatory restrictions on activities and market-based instruments can be complementary. For example, restrictions can be used to prevent irreversible and dangerous outcomes, like safe-minimum standards, and market-based instruments can be used to induce effective outcomes that go beyond these limits.

3. The full range of market-based instruments applicable for conservation instruments

Table 1 provides a summary of policy instruments conventionally deemed to be market-based.

4. Price-based instruments, such as taxes, fees, and penalties, for undesirable behaviours

These incentives have in common the fact that there is some "price" placed on an undesirable or desirable behaviour. There may be legal distinctions between taxes and fees, fees interpreted as a price for services "received." How and where taxes or fees can be levied depends on statutory or judicial requirements. Penalties are a "price" placed on proscribed or prohibited behaviours, and are punishments for violating, for example, legal responsibilities.

4.1 Opportunities related to taxes, fees and penalties

These pricing instruments may be effective in circumstances where there is clearly something to place a price on and where payments are collectable. Thus, the most commonly used price-based conservation related instruments

Table 1: Summary of policy instruments conventionally deemed to be market-based

Type	Instrument	Definition
Price-based instruments for undesirable behaviours	Direct	a compulsory unrequited payment not proportional to the good or service received in return for that payment.
	Fees Penalties Input/ output taxes	Price paid in remuneration for specific services.
Price-based instruments to reward desirable behaviours	Subsidies	an unrequited current payment for provision of a good or service.
	Indirect fiscal	fiscal incentives such as tax exemptions, capital grants, price guarantees and the provision of cheap credit.
	Payment for ecosystem services	A voluntary transaction in which an environmental service is bought by a minimum of one service buyer who, in return, compensates a minimum of one service provider, if and only if the provider secures that service.
	Conservation easements	A legal agreement between a landowner and another entity, that permanently limits land uses of the property in order to protect conservation values.
	Auctions	Competitive tendering process.
Price-based liability approaches	Deposit refunds	Monetary deposits paid by consumers at the time of purchase and returnable when items are returned.
	Performance bonds	Deposits required from extractive industries refundable if the payer fulfils certain obligations.
Quantity-based instruments	Cap and Trade	Markets in which established rights or allowances can be exchanged.
	Biodiversity offsets	Conservation actions intended to compensate for the residual, unavoidable harm to biodiversity caused by development projects, so as to ensure 'no net loss' of biodiversity.
	Tradable development rights	Rights to develop in conservation areas that can be sold for development rights outside a restricted area.
	Individual Tradable Quotas	Output/production controls that assign exclusive individual rights to harvest specific portions of an overall natural resource quota.
Product-based instruments	Ecolabels	Information systems for consumer products confirming the product has been produced in accordance with certain environmental standards
	Certification	Process of certifying claims made in relation to environmental standards.

include hunting, logging and fishing licenses, timber harvest taxes, export and import fees for traded flora and fauna, and protected area user fees. Timber harvest taxes are used in some developing countries although experiences with them have not always been encouraging (Kim *et al.* 2006). Timber harvest taxes should be based upon the full costs of logging

activities, otherwise there will be too much timber harvested relative to other uses of resources. These costs include not only direct logging costs, but also the costs of opportunities foregone, which may include the ecosystem services lost with forest conversion (Yaron 2001). With forestry, taxes to reduce harvesting could result in a wide range of ecological benefits in addition to just limiting biomass removal. Setting such taxes in a non-arbitrary manner is the key to using taxes for conservation. Knowing the ecological impacts of timber harvests, and evaluating those impacts in economic terms will be an important element in implementing such a tax.

Taxes are useful in resource use cases, where the behaviour is observable, there is something to tax, there is an identifiable agent to tax and property rights can be clearly established. If observation is difficult, punitive penalties may be the only meaningful deterrent, where penalties are set so high that they are extremely onerous if one is caught. Higher penalties must offset the higher likelihood that one will not be caught. Of course, the functioning of taxes is predicated on state capacity to collect taxes and to keep corruption at bay.

Taxes have been used in several developed countries such as the Netherlands, Sweden, and the United States to control nitrogen discharges from agricultural non-point sources. The primary motivations were to protect water quality and human health by such taxes, and also enhance riparian environments. Generally, an instrument will be more efficient the closer it is applied to the environmental damage but input taxes can be attractive instruments for controlling discharges from numerous non-point sources, because they entail lower monitoring and enforcement costs than other instruments, such as technological requirements. In Sweden, a tax of 0.2 Euros or about $ 0.25 per kilogram of nitrogen has reduced nitrogen utilization in agriculture by about 10 per cent (OECD 2001). Similar taxes have been introduced for pesticides. Although not common in developing country contexts, input taxes may have potential because they are relatively easy to implement with limited informational and institutional demands.

It is conceivable that the external costs of loss of biodiversity, associated with clearing native vegetation could be subject to tax but to date, such taxation has not been directly associated with conservation.

The tax system can be used to notionally capture willingness to pay for conservation in addition to making polluters pay for damage. Belize charges a tourist tax of $3.75 for each passenger arriving in country by plane or cruise ship, with the proceeds going to a national conservation trust that supports protected areas and other conservation activities. Costa Rica and other countries impose a tourism tax on the price of hotel rooms, some of which is earmarked for conservation. Fees are one of the easiest and most common price-based instruments for capturing willingness to pay and may cover access to protected areas or associated activities related to conservation (photography permits). Evidence suggest that fees charged do not always fully cover the willingness to pay of tourists attracted by nature (Naidoo and Adamowicz 2005)

4.2 Pitfalls

4.2.1 *Failure to define and assign property rights*

A critical requirement for price-based instruments is that the property rights associated with the "good or service" being priced are well-established and enforced. For example, setting a price on the degradation of wetlands will have no meaning if there is confusion about who "owns" the wetlands. The good or service that is priced must be clear, its units well measurable, and the rights well-established. These instruments will not work well where the institutions or cultural conditions are not conducive to establishing and accepting the concept of property rights.

4.2.2 *Behaviour must be observable and enforceable*

One precondition for the success of price-based approaches is that the behaviour be observable and capable of being monitored. This is not always the case; for example, in the enforcement of conservation easements in remote areas, or penalties for prohibited species takes or harvesting behaviour. Enforcement may be formal, such as monitoring by a resource agency, or informal, such as watchful citizens. The inability to adequately observe behaviour can lead to self interested agents avoiding compliance with contractual obligations. It can also lead to perverse effects such as the incentive to destroy an endangered species or habitat on one's property before it is discovered (Polasky and Doremus 1998; Lueck and Michael 2003). Developing countries, in particular, may have difficulty in collecting taxes or fees, and enforcing compliance with a price-based conservation system.

4.2.3 *Price incentives are most effective the more directly related to the undesirable behaviour*

The success of these incentives also depends upon the extent to which the "price" is directly related to the undesirable behaviour. While it may be more administratively convenient to levy the price on one behaviour, if this is not highly correlated with the undesirable behaviour, incentives are reduced and the instrument less effective. For example, suppose the sole conservation objective is to protect an endangered species from capture by humans; then a penalty levied on harm or harassment of a species would be the most

direct instrument. But suppose it is difficult or impossible to measure species harm directly. A second-best instrument may be a penalty for degradation of habitat associated with that species. This may still allow an agent to take the species by hunting even when the associated habitat remains undisturbed.

4.2.4 *Price incentives must be set at the proper margins of behaviour*

Price incentives must also be on the proper margins of behaviour to compel agents to respond in a desirable manner. For example, setting land development fees at a fixed rate independent of the level of land conversion creates fewer conservation incentives compared to a fee based on the amount of conversion. This is the same issue faced in designing fees for water use; a fixed fee may not induce consumers and firms to cut back on water use. The downside to pricing on the proper margins of behaviour is that agents may attempt to avoid the levies through undesirable actions; e.g., illegal habitat conversion or water theft. So, enforcement of the levies may require observing both legal and illegal behaviours.

4.2.5 *Prices must be set at the correct levels*

Setting prices at the correct level is another precondition for success. In general, if we want to see behaviour at a certain level, such as a number of acres remaining undeveloped, we must know what the cost of that behaviour is for agents in terms of the benefits foregone from not pursing alternative options. Then the prices must be set at a level somewhat in excess of that cost. If the price is set too low, it is cheaper for the agent to pay the tax, fee, or penalty, than to engage in the behaviour we seek to achieve. For example, if a landowner can obtain an additional income of $100 from some activity we would like to discourage, a price of at least $100 must be levied to discourage that behaviour. Unfortunately, we cannot always know these costs to agents. The more uncertain we are about agent costs, the more likely it is that prices will have to be altered to achieve acceptable outcomes. This problem arises because of imperfect information about the opportunity costs agents face and compounded by the fact that agents, whose behaviour we seek to change, may face very different opportunity costs for undertaking the same actions. Auction mechanisms are one means of addressing this informational asymmetry. If there is considerable likelihood that some behaviour could be especially deleterious, it may be more useful to simply proscribe the behaviour rather than use the more subtle pricing instrument. An example would be if it is absolutely critical to maintain a given area of wetlands for a critical conservation goal. Directly proscribing or prohibiting wetlands degradation may be more effective than using pricing instruments to ensure behaviour commensurate with the required habitat extent.

If pricing is based upon the benefits lost from some undesirable behaviour, a measure of these benefits must be established. For example, we must know the marginal value of wetlands services before we can set a benefits-based price on behaviours that degrade those services. This may not be simple. It may be easier to establish the cost to an agent for not engaging in the undesirable behaviour, suggesting that a cost-based price would be administratively easier.

When enforcement is uncertain, it is reasonable to consider setting prices at higher levels to account for the uncertainty. For example, suppose we wanted agents to effectively incorporate a price of $100 into their decision calculus before deciding to engage in some undesirable behaviour, such as dumping wastes into streams. But suppose there is only a 10 per cent chance that such behaviour will be observed by the enforcers. Then setting a price of $1000 would result in an expected price of $100 (10% x $1000). This is one of the arguments to assigning punitive damages; that enforcement is uncertain and it signals to other agents that the price of their undesirable behaviour will be high if they are caught. In this example, actual damages would be only $100, but the punitive damages would be $900.

4.2.6 *Uncertainty about expected benefits*

Another basis of pricing of behaviours is the benefits we expect to obtain when that behaviour is avoided. Under this interpretation, if the benefit of avoiding dumping into streams is $100, then setting the price at $100 at least allows recouping of damages. But if we do not know these benefits or they cannot be evaluated in monetary units, which is often the case, then setting a price based on benefits received is problematic. In such cases, reverting to prescriptive or proscriptive rules, such as permits or mandated actions, may be prudent.

4.2.7 *Agents must be responsive to the pricing instrument*

Another precondition for using these pricing instruments is that agents are responsive to these prices. It may be that agents are not highly rational, or do not make decisions based upon the same costs and benefits units as the prices. While pricing is perfectly general, i.e., the price can be monetary, or time, or chickens, etc., the prices may be in units that do not stimulate behaviour. The prices must have meaning. Monetary prices in a culture that is not highly monetized, or market oriented, may not be very effective. Also, there may be social reluctance to accept prices for things that were traditionally free.

4.2.8 *Inadvertent distributional consequences*

Such price-based mechanisms conform with the polluter pays principle with the statutory incidence of the tax falling on the polluter. The economic incidence of the tax may not. Depending in part on the elasticity of demand for the goods or services incurring the tax, businesses can pass on the tax in the form of higher prices for buyers, lower wages to workers or lower returns to investors.

5. Payments and Subsidies

Subsidies or payments for ecosystem services are the opposite of taxes, fees and penalties, and place prices on desirable behaviours. There is an important distinction between the two instruments. A payment for a service sets a price on the service, and agents can decide whether they wish to "sell" that service. A subsidy represents compensation to an agent for engaging in a desirable activity; the compensation can be direct or indirect, as in the case of tax breaks. The "pay for service" may have a different image to the public than the "subsidy for an activity." While subsidies are sometimes the cause of conservation problems, such as subsidies to the fishing industry that result in over-fishing (Myers and Kent 2001; Fujita *et al.* 2004) or agricultural subsidies that result in overuse of land, they can also be used to achieve environmental objectives. Payments for ecosystem services, where "producers" of environmental services (e.g., landholders whose forested land filters water) are compensated by "consumers" (e.g., downstream water users), are one such rapidly emerging mechanism. Despite their increasing popularity, these instruments do have pitfalls that need careful consideration. Payment systems include both fixed prices as well as auction-based prices.

5.1 Opportunities related to subsidies and payments

Subsidies and payments may be more effective than taxes, fees, or penalties in certain instances. For example, if an agent has the right to an activity, such as the right to develop land, subsidies or payments may be the only price-based instrument available to deter that activity under the initial assignment of property rights. This may be necessary in the case of species protection, as the legal battles in the US over the Endangered Species Act suggest. Paying people to save species rather than penalizing them if they do not may be a useful, albeit expensive, solution (Jenkins *et al.* 2004). Also, compensating persons who have been harmed as a result of conservation programs, such as farmers whose crops are damaged by preserving elephant herds, would increase the likelihood of harmed parties agreeing to the programs. It may be less costly simply to pay agents to do something rather than face what may be protracted legal costs.

Subsidies and payments may also be the most useful instrument when equity issues dominate a conservation objective. In many instances, conservation requires a few to bear the costs that benefit many. If this circumstance is viewed as too unfair, giving a subsidy may be more acceptable than a tax, fee or penalty. This may be particularly important in agriculture, as farmers are often viewed as being marginal economic enterprises.

Subsidy programs may offset costs to agents of engaging in conservation activities. Subsidies may be in the form of tax deductions or coverage of costs. For example, a Brazilian program, ICMS Ecológico, awards a share of national sales tax collections to municipalities if they engage in programs to establish restricted areas (Grieg-Gran 2000). This is presumably to offset the costs in lost revenues to municipalities from restrictions on land use and development. Ontario, Canada, has a tax incentive program for land conservation, whereby landowners can receive 100% property tax relief for preserving land in acceptable condition. Eligible lands include provincially "significant" wetlands, habitats for endangered species, and lands of natural and scientific interest. (http://www.mnr.gov.on.ca/MNR/cltip/).

The Environmental Stewardship program in England is a good example of a payment scheme (http://www.defra.gov.uk/erdp/schemes/es/default.htm). Farmers receive payments per hectare in return for accepting a package of management measures. Each management option receives a number of points, and the farmer is then paid based on the number of accumulated points. Points can be awarded based upon national or local significance and priorities. Since the program began in 2006, over 3 million hectares have been enrolled with 23,000 agreements and over £105 million have been paid.

In developing nations with weak regulatory and taxation systems, paying for ecosystem conservation may be one of the most effective ways to achieve conservation goals. The best known ecosystem service payment system outside of high-income nations is the one established by Costa Rica in 1995. The scheme was designed to enhance and sustain forested ecosystem services, including carbon sequestration, biodiversity, watershed management, and landscape beauty. The program pays landowners US$202/ha for forest protection, US$314/ha for sustainable forest management, and US$516/ha for reforestation (Miranda *et al.* 2004) for a contracted five years of protection. The state's National Forestry Finance Fund (FONAFIFO) purchases these services, then sells them to interested buyers. For example, it may sell carbon sequestration credits to international buyers, watershed management credits to national hydroelectric utility companies. So it is a hybrid purchase and trading program,

where the state is the trading agent.

Literature on information economics has forced policy makers to reassess policy mechanisms employed for many policy problems and has led to increasing interest in auction based approaches for publicly funded biodiversity programs rather than fixed price approaches (Stoneham *et al.* 2003). In negotiating biodiversity contracts, the conservation agency and potential participant will have varying information regarding the ecological worth of landholdings and on the opportunity costs of conservation. Auctions can help address this information asymmetry and potentially achieve greater conservation outcomes at lower cost than fixed payment schemes. The Australian Catchment Care program is an example of such an auction-based scheme to achieve cost-effective natural resource management actions (http://www.napswq.gov.au/mbi/round1/project26.html). In this recently developed program, landholders bid for contracts to establish conservation activities. These activities are scored on the bases of environmental value and threats. The score is then related to the proposed landholder cost; and proposed contracts are ranked on a cost-effective basis. Contracts are established for the most cost-effective bids until funds are exhausted or a reservation cost-effective price is reached. A full trial of the scheme was run in a watershed, where 29 bids were submitted, and 17 were selected for funding.

Another example of an auction-based payment scheme is the Bush Tender program in Australia (http://www.ecosystemservicesproject.org/html/publications/docs/Intro_to_MBIs_2005.pdf). Farmers proposed bids for projects that were then ranked by their biodiversity benefits. Winning bids were then selected based on their cost-effectiveness. Analysis of the program concluded that the auction approach delivered 25% more native vegetation for the same cost as a grants scheme.

The auction-based payment schemes are useful as they utilize competitive forces to achieve the most cost-effective conservation goals. However, they are administratively complex and require measurements of conservation outcomes, a task that may not be simple, depending on the outcomes desired. Useful measures of outcomes require more than just measures of land area impacted.

Payment schemes are not limited to government sponsored programs. Private agents may have sufficient incentives to pay for services useful to them. As noted, the Perrier-Vittel company, which sells bottled water, has financed reforestation and is working with farmers to develop less polluting management practices (The Economist 2005). In South Africa, a private ecotourism company, Conscorp, pays landowners to restore farmlands and stock them with native wildlife (Heal 1998). These are good examples of Coase's argument that government intervention may not always be necessary to manage externalities.

Both public sponsored and self organized deals have also created markets based on the establishment of property rights and the environmental aspects of assets, such as non-developed state of land. Development rights and other rights can be distinguished from other property rights and traded separately by using, for example, conservation easements.

Land trusts and conservation easements are widely used in the United States and elsewhere to pursue conservation goals. Land trusts purchase land for conservation or buy development rights or conservation easements on land which remains in external ownership. In Indiana, Sycamore Land Trust has been one flexible tool for attaining local conservation goals without the involvement of the state (York *et al.* 2006) and land trusts have also been used in the Mountain West for landscape and open space preservation (Booth 2002). However, land trusts allocate the costs of conservation to the public, which means that availability of funds will curtail the volume of conservation. Enforcement of easements in the courts can also be costly and the continuity of land trust depends on private donations. There is also a possibility of conflict between local and wider conservation goals and priorities.

Tradable development rights may be useful to achieve land-based conservation objectives. The initial assignment of rights is critical to the acceptability of this instrument, as is the question of who can buy these rights. Trading rules must be well-defined and administered, as these rights may be economically meaningful and contentious assets. These rights may be either in the form of tradable rights to develop, or as development "reduction" credits. Conservation groups may be given the right to purchase. As in the case of all these market-based instruments, monitoring and enforcement are critical to success. Assuring that development does not occur where proscribed may not be easy. For example, Brazil is allowing such trading under its general rule that requires landowners in the Amazon forest to maintain half of their land in forest (Jenkins *et al.* 2004).

5.2 Pitfalls related to subsidies and payments

5.2.1 *Property rights must be well-defined*

Altering behaviour is costly and these costs are the same to society whether subsidies (payments) or taxes (fees and penalties) are used to alter behaviour. The type of price used, subsidy or tax, defines property rights in status quo and determines who bears the cost of that change. Taxes leave the cost to private agent while subsidies redistribute the cost in part or in whole to the public. The argument for just compensation in takings is also based on the fairness issue of

who should bear the cost of an action.

5.2.2 *Political difficulties*

Subsidies may face political difficulties, as they may be viewed as paying agents to do something they should already be doing according to local norms or customs. For example, paying someone to stop using land in a certain way may be seen as implicitly sanctioning a use that was formerly taboo. Payments for actions may be viewed as more acceptable; even the terms "subsidy" and "payment" have different connotations.

5.2.3 *Financial limitations*

Subsidies and payments require funds to finance or can result in the loss of government revenues in the case of tax breaks. Financial limitations may restrict the use of subsidies.

5.2.4 *Permanence of outcome*

Related to financial limitations is the issue of permanence, a factor which must be considered when assessing appropriate mechanisms for biodiversity or ecosystem services. Assume a farmer is paid, through auction or subsidy, to fence off a stretch of native vegetation. When payments cease, she allows her cattle to graze the area, so that most of the benefits of biodiversity conservation will be lost. With water quality, in contrast, the benefits from the service of water purification will have been enjoyed throughout the contract.

5.2.5 *Perverse incentives*

Subsidies and payments can create perverse incentives. A subsidy or payment to avoid an activity may induce agents to engage in more of that activity. For example, paying agents to cease polluting a stream may cause them to want to increase proposed discharges in order to obtain higher subsidy payments. Subsidies and payments may also encourage entry and delay exit from an industry, exacerbating the original conservation issue. This latter issue is most likely to be a problem when the most inefficient firms/farmers are also the most environmentally damaging.

5.2.5 *Equity considerations*

In the Costa Rican example above, it is only farmers with property rights to land who can be paid for conservation.

5.2.6 *Costs of monitoring and enforcement*

Payments and subsidies are paid for taking specific actions, such as adhering to a specific land management plan, building storage capacity for manure, or setting land aside from cultivation. Their effectiveness depends on the ability to monitor compliance with applicable conditions and on the enforcement of these conditions. In many cases monitoring of compliance and enforcement are costly, which means that implementation and outcomes can fall short of the goals.

6. Deposit refund instruments

Deposit-refund instruments are specialized types of pricing instruments. Typically, a deposit is paid up front for an item or action, and a refund is given upon completion of some desirable action, such as return of the item or meeting some action criterion. Performance bonds require an up-front liability and, if the terms of environmental management are satisfied, the liability disappears.

6.1 Opportunities related to deposit refund instruments

Deposit-refunds on hazardous materials, such as oil and batteries can be helpful in reducing disposal risks and can therefore have a minor role to play in enhancing conservation. Performance bonds can play a more important role in achieving conservation or remediation objectives. These bonds are used in the US to secure funds to meet surface mining reclamation requirements. The mining company Gold Field's 2003 Annual Report noting that in Ghana, it funds environmental rehabilitation costs by posting a US$3 million reclamation bond, while in Australia, it guarantees its environmental obligations by providing the western Australian government with unconditional bank-guaranteed performance bonds to the amount of AUS$12.3 million. Whether such bonds are large enough, or remediation objectives are actually met are serious questions for the use of these instruments. For example, the state of Pennsylvania has had mining reclamation bonds in place for a long time, but the costs of acid mine drainage remediation have dwarfed the bond fund, leaving the citizens of the state with major unfunded cleanup costs. Bonds could be used to assure proper timber practices, as a pre-condition for wetlands development or as a condition for receiving a fishing permit.

6.2 Pitfalls related to deposit refund instruments

6.2.1 *Certifiability*

Pre-conditions for success of this instrument include certifiability that a deposit was paid on the items or actions for which refunds are claimed, and that the items or actions are as claimed. This is a problem, for example, in the recycling of used oil; the returned oil can be contaminated or purchased where deposits were not required. It is a problem with performance requirements for ecosystem restoration; a long monitoring period may be necessary to assess whether performance criteria are met. Such a long time period may be financially or politically unacceptable.

7. Quantity-based instruments involving market creation and trading

Whereas price-based instruments, notably taxes, provide security regarding the cost of a policy objective, quantity based instruments provide more certainty as regards specific policy objectives. These instruments rely upon the incentives of agents to trade responsibilities amongst one another. The classic cases are tradable permits for pollutants, such as sulphur dioxide and carbon dioxide, and tradable fishing quotas. The trades may be based on allowances, such as permitted emissions or fish catch, or on reductions, such as emissions reduction credits or reductions in fishing effort. Typically, agents are assigned some initial responsibility, e.g., allowable emissions, or required reductions, and if some agents are more successful than others in meeting those responsibilities they can trade responsibilities. Although there have been some voluntary cap and trade schemes, most such schemes depend on well-defined, enforceable legal and regulatory frameworks

7.1 Opportunities related to Trading

Tradable fishing rights have been used by a number of developed countries to manage fish stocks. Although resource management underlies their introduction, regulating fishing contributes directly to the wider health of marine ecosystems (McIntyre *et al.* 2007). Setting the allowable catch and then dividing up the rights can be difficult, requiring scientific, economic, and community knowledge. Enforcement can also be a problem, but can range from formal to community actions. Using trading instruments for more complicated conservation objectives may be problematic. Biodiversity conservation is complicated by the fact that there is a multitude of species and interactions that must be preserved. Trading based upon species, per se, or even "bundles" of species would not be a very effective or practical means of protecting biodiversity. Rather, trading of habitats, perhaps weighted for species potential or richness, may be a more useful application of trading. Australia is proposing a program creating tradable rights for landowners who conserve biodiversity on their land; and developers must obtain such rights from a common pool in order to develop land (Jenkins *et al.* 2004). Perhaps the most developed program for biodiversity mitigation is the US wetland banking program introduced under the Clean Water Act of 1972, where wetlands qualities can be used as weights (e.g., Habitat Units) for measuring credits. Both schemes are based on the notion of 'no net loss' of biodiversity. Some researchers have proposed tradable invasive species permits to protect biodiversity (Horan and Lupi 2005).

Another useful example is the recently developed scheme for protecting marine resources in a heavily trawl-damaged area off the coast of California (New York Times 2006). In order to reduce trawl fishing, several non-profit environmental groups have begun purchasing fishing permits from fishermen along the central California coast. The purchases, at a cost of several hundred thousand each, include both the permits and the boats. The environmental organizations then own the boats and permits, and can lease these to fishermen with restrictions on fishing locations and techniques. This would not have been a useful tool if the fishermen would have changed their locations and techniques favourably without the buy-out; but this did not seem to be the case.

In response to regulatory requirements for compensatory mitigation, conservation banks have been established to generate credits for habitat restoration. Conservation banks have been established to mitigate damage to a wide variety of ecosystems, including short-grass prairie and old-growth pine forests in the United States. The most well-known example of conservation banking is the U.S. wetlands banking programs that allow agents to bank and buy wetlands restoration and development credits. There are over 500 wetland mitigation banks operating. When mitigation ratios are set above 1:1, there can presumably be a net gain in wetlands. However, the extent to which banked wetlands represent the same functionality as developed wetlands, and the extent to which the banked wetlands are successful over the long term, limit the possible net gains (Salzman and Ruhl 2001).

Australia has used a trade mechanism to achieve cost-effective salt load reductions in the Hunter River (http://www.ecosystemservicesproject.org/html/publications/docs/Intro_to_MBIs_2005.pdf). Individual polluters are given initial licenses to discharge a given quantity of salt into the river. Polluters can then trade amongst themselves.

7.2 Pitfalls related to Market Creation and Trading

7.2.1 *Assignment and rights, and equity implications*

There must always be an initial assignment of rights. These will often be politically contentious. "Grandfathering" and auctioning are two possible assignment procedures for cap and trade schemes, each with their economic and equity implications. When the value of the permits is high, the initial assignment has significant financial equity implications, and also affects the trading itself. An agent with an initially large assignment has a significant asset, and may use that asset in undesirable ways. For example, if a few agents receive a large number of land development rights, they may be able to control development to their advantage simply by the possession of these rights; they may use them to drive

competitors out of business. In the Netherlands, large companies buy up fishing quotas and lease them to small operators, who receive little profits from their catch (www.colby.edu/personal/t/thtieten/fish-nz.html).

7.2.2 *Measurability and verifiability*

Pre-conditions for successful trading schemes include measurability and verifiability of trades. Tradable permits for pollutants meet these requirements, particularly in those countries that have well-developed permitting and measurement systems. But it is always possible for an agent to cheat by claiming fewer pollutants or greater reductions than is the case; or falsely claiming to have purchased more allowances or reduction credits than is the case. It is not inexpensive to measure and monitor trading schemes.

7.2.3 *Well-functioning trading market*

Another pre-condition for a successful trading scheme is that the trading market be well-functioning, meaning that trades are made when there are mutually beneficial circumstances for the traders. Small trading markets can be monopolized, defeating the presumed benefits of trading. Also, information must be available on what is for sale and who wants to buy. If there are willing buyers and sellers but they cannot find one another easily, the market will function at less than its potential.

7.2.4 *High transaction costs*

Trading involves transactions costs, such as finding sellers and buyers, and establishing the terms of trade. This may be a problem in the case of the CDM of the Kyoto Protocol where potential reforestation and afforestation projects involve many small landholders. Transaction costs can be so high as to prevent the project from going ahead, creating a barrier to small-holders entering the market and trading their carbon credits.

7.2.5 *Cultural pitfalls and strategic bargaining*

Trading schemes may not work in cultures that cannot understand the concepts of trading in such unfamiliar items as rights and actions. And they may not be successful in circumstance where agents are reluctant to give up presumed rights. This has been a problem in establishing water use rights trading in the Western US. While there is a huge difference between the low economic value of water use in agriculture and the high value of water in urban areas, farmers have been reluctant to give up water rights as that may forever alter their ability to farm. While there may be a high enough price at which a farmer will sell, this high price may foreclose any trades of water from low to high value uses. Strategic bargaining between trading parties may lengthen the trading process and even result in the foreclosure of what otherwise could have been mutually advantageous trades. A farmer may begin the bargaining by stating such a high price that buyers presume no reasonable deal can be made, or buyers set initially low prices that sellers walk away; this is a noted issue in residential house sales. The attempts to institute tradable quotas in New Zealand fisheries in the early 1980s were not accepted by the Maori people since it did not coincide with their view of common property resources.

7.2.6 *"Hot spot" problem*

Trading schemes must be set up to avoid adverse environmental consequences. Typically, trading results in shifting activities spatially. There are problems with trading schemes that result in too much of an adverse activity or too little of an activity in one location. An example of this problem can be found in the context of wetland mitigation banking (Salzman and Ruhl 2006). Although there may be no net loss in wetland area, wetlands near urban areas, where the hydrological services are most valuable, are increasingly being destroyed while, in exchange, wetlands are restored in rural areas. This problem can be remedied by restricting trades between donor and recipient regions. But this adds one more layer of administrative complication, which raises the costs. If the hot spot problem is too severe, trading may not be a good idea

7.2.7 *Assuring improvements in environmental objectives*

If desirable environmental behaviours would have taken place in absence of the trading, this market instrument adds nothing to meaningful policy tools. For example, in the case of carbon trading, if an agent receives reduction credits for actions that would be taken anyway, such as reduced timbering, reforestation or emissions reductions, the tradable permit just gives the agent added wealth. However, determining whether an action would have been taken in the absence of the permits is difficult. This risk may be small relative to what can be gained more broadly from the use of tradable permits. There will likely be errors in administration, but these may be acceptable relative to the potential gains from institutionalizing and obtaining acceptance of trading.

8. Demand enhancement

Providing a market environment in which appropriate behaviour enhances the market demand for an agent's products or services creates a reward for that behaviour. Green goods, such as organically grown coffee, are examples. These goods may be formally or informally certified, even receiving "seals of approval." Agents may create their own advertising

around the good characteristics of their products, production processes or agent behaviour unrelated to the product. This may enhance the products' distinctiveness, resulting in larger sales or price premiums. While these demand-enhancing, market-based programs may be useful in achieving environmental objectives they have well-known pitfalls.

8.1 Opportunities related to demand enhancement

A potentially useful opportunity ties agent conservation activities and land practices to the agent's products. Timbering and farming practices could be certified as conservation "friendly" and, as in the case of organically grown products, may bear a premium in the market. Banrock Station winery in Australia markets its participation in the management of Banrock Station wetlands and its contributions to wetland conservation. Shade-grown coffee, which aims to protect forest canopies for wildlife, is another well-known example of tying a private good to a public environmental good. Another example is the certification program of the Forest Stewardship Council that certifies individuals or corporations as practicing good forest management (http://www.fsc.org). Although most certification programs focus on habitat protection, there are a few associated with the harvesting of individual animals or plants, such as the Marine Aquarium Council's program to certify fish harvesting practices in the international aquarium trade.

8.2 Pitfalls related to demand enhancement

8.2.1 *Value added*

A major pitfall is whether there would be enough demand enhancement to merit the agent's effort. Some products or services receive no value-added from being characterized as "green". In other cases, consumers may be willing to pay more for a green product, but not enough to cover the increased costs associated with producing the environmentally-friendly commodity.

8.2.2 *Certification and monitoring*

A second pitfall is the certification process and subsequent monitoring. If certification has no basis in fact, false claims by agents will make consumers leery of certification. There may also be confusion about whether a product is really good for the environment, particularly when the product has both pluses and minuses. Once certification is obtained, agents may alter their products in ways that make them less green; so regular monitoring and recertification is necessary.

Maintaining the distinction of the product may be difficult when there are not separate market distribution networks that keep the friendly products distinct from others. This may be increasingly true as globalization of product markets erases the distinctiveness and origin of products.

8.2.3 *Competition in industry*

While certification can be useful in enhancing product demand, it also has the potential to be used to restrict entry into an industry. For example, while organic products may distinguish sellers, organic certification processes may be so tailored and complicated by existing organic farmers that they create barriers to entry into the industry.

8.2.4 *Sharing the benefits*

Price premiums associated with biodiversity friendly products need to be channelled back to producers. Evidence suggests that with some products it is traders and middlemen who gain disproportionately (Bacon 2005).

8.2.5 *Disadvantaging poor producers*

There is some reluctance and scepticism surrounding motives for introducing eco-labelling and certification schemes given that they inadvertently discriminate against producers who meet the criteria but are not participating in a scheme.

8.2.5 *Label Fatigue*

From the perspective of the consumer, a proliferation of certification schemes

CONCLUSION

Conservation activities are always fraught with issues of costs, benefits, disproportionate impacts, monitoring and enforcement. Market-based instruments can be useful if they help achieve conservation objectives at lower costs, with higher benefits, without undue adverse impacts on selected persons, and with more manageable monitoring and enforcement. Market-based instruments that place prices on ecological services, land uses or other activities establish obligations to pay for what is lost, or receive payment for what is gained. Clear pricing signals make economic calculations regarding conservation activities relatively straightforward, and can be fine tuned to establish many conservation objectives. These instruments can either be punitive, as taxes or fees, or rewarding, such as subsidies and payments. Trading instruments allow for the transferof responsibilities to agents most able to gain, such as those who can achieve conservation objectives most cost-effectively. These instruments can facilitate achieving conservation goals most cheaply and, consequently, may allow for the establishment of even higher objectives.

Demand-based instruments may be somewhat less clear cut than the pricing and trading instruments, since it is not clear how the market demand for an agent's products will be enhanced through the conservation activities. Financial instruments, such as deposit-refund programs or performance bonds, can establish clear, long-term signals regarding whether conservation objectives have actually been achieved.

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REFERENCES

Bacon, C. (2005): Confronting the Coffee Crisis: can fair trade, organic and speciality coffees reduce small-scale farmer vulnerability in Northern Nicaragua? *World Development 33*: 497-511.

Balmford, A., A. Bruner, P. Cooper, R. Costanza, S. Farber, R.E. Green, M. Jenkins, P. Jefferiss, V. Jessamy, J. Madden, K. Munro, N. Myers, S. Naeem, J. Paavola, M. Rayment, S. Rosendo, J. Roughgarden, K. Trumper & R.K. Turner (2002): Economic Reasons for Conserving Wild Nature. *Science 297*: 950-953.

Booth, D. (2002): Searching for Paradise: Economic Development and Environmental Change in the Mountain West. Rowman & Littlefield. Lanham, MD.

Boyd, J.W. & H.S. Banzhaf (2005): Ecosystem Services and Government Accountability: The Need for a New Way of Judging Nature's Value. *Resources, Summer 2005*: 16-19.

Cheung, S. (1973): The Fable of the Bees: An Economic Investigation. *Journal of Law and Economics 16*: 11-33.

Coase, R.H. (1960): The problem of social cost. *Journal of Law and Economics 3*: 1-44.

Coase, R.H. (1974): The lighthouse in economics. *Journal of Law and Economics 17*: 357-376.

Costanza, R., R. d'Arge, R. de Groot, S. Farber, M. Grasso, B. Hannon, K. Limburg, S. Naeem, R.V. O'Neill, J. Paruelo, R.G. Raskin, P. Sutton & M. van den Belt (1997): The value of the world's ecosystem services and natural capital. *Nature 387*: 253-260.

DeGroot, R.S., M.A. Wilson & R.M.J. Boumans (2002): A typology for the classification, description and valuation of ecosystem functions, goods and services. *Ecological Economics 41*: 393-408.

Farber, S., R. Costanza, D.L. Childers, Jon Erickson, K. Gross, M. Grove, C.S. Hopkinson, J. Kahn, S. Pincetl, A. Troy, P. Warren & M. Wilson (2006): Linking Ecology and Economics for Ecosystem Management. *BioScience 56*: 121-133.

Fujita, R., K. Bonzon, J. Wilen, A. Solow, R. Arnason, J. Cannon & S. Polasky (2004): Rationality or Chaos? Global Fisheries at the Crossroads. *In*: Glover, L. & S. Earle (Eds): Defying Ocean's End: An Agenda for Action. (Island Press, Washington, DC).

Grieg-Gran, M. (2000): Fiscal Incentives for Biodiversity Conservation: The ICMS Ecológico in Brazil. Discussion paper 00-01. London: International Institute for Environment and Development.

Heal, G. (1998): Markets and Sustainability, working paper PW-98-02, Columbia Business School, Columbia University, New York.

Horan, R. & F. Lupi (2005): Tradeable Risk Permits to Prevent Future Introductions of Invasive Alien Species into the Great Lakes. *Ecological Economics 52*: 289-304.

Jenkins, M., S. Scherr & M. Inbar (2004): Markets for Biodiversity Services: Potential Roles and Challenges. *Environment 46(6)*: 32-42.

Kim, S., N.K. Phat, M. Koike & H. Hayashi (2006): Estimating actual and potential government revenues from timber harvesting in Cambodia. Forest Policy and Economics *8*: 625-635.

Landell-Mills, N. & I.T. Porras (2002): Silver Bullet or Fool's Gold: a Global Review of Markets for Forest Environmental Services and their Impact on the Poor. London: International Institute for Environment and Development.

Lueck, D. & J.A. Michael (2003): Pre-emptive habitat destruction under the Endangered Species Act. *Journal of Law and Economics 46(1)*: 27-60.

McIntyre, P., L. Jones, S. Flecker & M. Vanni (2007): Fish extinction alter nutrient recycling in tropical freshwaters. *Proceedings of the National Academy of Science in the United States of America 104(11)*: 4461-4466.

Mero, D., (2002): Financing reforestation for improved watershed management in the Philippines. *EFTRN News 35*: 44-45. Wageningen.

Miranda, M., I. Porras & M.L. Moreno (2004): The Social Impacts of Carbon Markets in Costa Rica: A Case Study of the Huetar Norte Region, London: International Institute for Economic Development.

Myers, N. & J. Kent (2001): Perverse Subsidies: How Tax Dollars Harm the Environment and the Economy. (Island Press, Washington, DC).

Naidoo, R. & W.L. Adamowicz (2005): Economic Benefits of biodiversity exceed costs of conservation at an African rainforest reserve. *Proceedings of the National Academy of Sciences of the United States 102*: 16712-16716.

New York Times (August 8, 2006): Unlikely Partners Create Plan to Save Ocean Habitat Along with Fishing, p. D3.

OECD (2001): Environmentally related taxes in OECD countries: Issues and Strategies. OECD, Paris.

Ostrom, E. (1990): Governing the Commons: The Evolution of Institutions for Collective Action. Cambridge University Press, Cambridge.

Polasky, S. & H. Doremus (1998): When the Truth Hurts: Endangered Species Policy on Private Land with Incomplete Information. *Journal of Environmental Economics and Management 35(1)*: 22-47.

Porter, M.E. & C. van der Linde (1995): Toward a New Conception of the Environment-Competitiveness Relationship. *Journal of Economic Perspectives 9*: 97-118.

Project 88 Conference (1989): Proceedings of Harvard University's John F. Kennedy School of Government/Project 88 Conference. Discussion Paper P-89-01, Kennedy School of Government, Harvard University.

Reyes, V., O. Segura & P. Verweji (2002): Valuation of hydrological services provided by forest in Costa Rica. *ETFRN News 35*: 42-44. Wageningen.

Russell, C. & P. Powell (1996): Choosing Environmental Policy Tools.

Theoretical Cautions and Practical Considerations. IADB. Washington D.C.

SALZMAN, J. & J.B. RUHL (2001): Apples and Oranges: The Role of Currencies in Environmental Trading Markets. *Environmental Law Reporter 31*: 11438.

SALZMAN, J. & J.B. RUHL (2006): 'No Net Loss' - Instrument Choice in Wetlands Protection. *In*: Freeman, Jody & Charles D. Kolstad (Eds): Moving to Markets in Environmental Regulation: Twenty Years of Experience. Oxford University Press.

STAVINS, R. (2001): Lessons from the American experiment with market based environmental policies. Resources for the future discussion Paper 01-53.

STONEHAM, G., V. CHAUDRI, A. HA & L. STRAPPAZON (2003): Auctions for conservation contracts: an empirical examination of Victoria's BushTender trial. *Australian Journal of Agricultural and Resource Economics 47(4)*: 477-500.

THE ECONOMIST (April 21, 2005): Are You Being Served?

TURNER, R.K., J. PAAVOLA, S. FARBER, P. COOPER, V. JESSAMY, S. ROSENDO & S. GEORGIOU (2003): Valuing Nature: Lessons Learnt and Future Research Directions. *Ecological Economics 46*: 493-510.

YARON, G. (2001): Forest, plantation crops or small-scale agriculture? An Economic analysis of alternative landuse options in the Mount Cameroon area. *Journal of Environmental Planning and Management 44(1)*: 85-108.

YORK, A.M., M.A. JANSSEN & L.A. CARLSON (2006): Diversity of incentives for private forest owners: An assessment of programs in Indiana, USA. *Land Use Policy 23*: 542-550.

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AGRICULTURE AND CONSERVATION

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Presentations

Rhys Green of RSPB and the University of Cambridge, UK, discussed reconciling crop production with biodiversity conservation. Agriculture is one of the biggest threats to biodiversity because it leads to extensive loss of habitat and the pesticide usage leads to environmental degradation. Agricultural environmentalists attempt to reconcile the two through two main practices – Land Sparing and Wildlife Friendly Farming.

Land Sparing concentrates on high intensity inputs and productivity on a portion of the land, leaving the remaining land free for biodiversity conservation. Land sparing, if followed properly, would have been successful in its objective. In practice, however, often when land is left uncultivated for biodiversity conservation, it is used for non-conservation processes like building roads and houses. This severely affects the feasibility of this form of biodiversity conservation.

Wildlife Friendly Farming is low in production and yield, but beneficial for the wildlife in the area. However, Wildlife Friendly Farming does not leave much land empty for pure biodiversity conservation. Both methods are likely to lower financial profits and farmers are compensated for economic losses that they suffer in order to help species survive. The viability of these methods also depends on the ecosystem of the area. Studies must be conducted before a method is chosen. With global food demands growing by two to three times by 2050 it is essential that we find methods of farming that can cater to the growing needs of the world as well as help conserve biodiversity.

Vijay Jardhari of the *Beej Bachao Andolan* (BBA, or Save the Seeds Movement), presented his experiences with conserving agro-biodiversity (agricultural biodiversity), in his village Jardhar in Uttarakhand, India, and in other parts of the region through the BBA. He tracked the changes in perceptions and methods of farming. Traditionally, farming was an esteemed profession and soil was a precious resource that had to be valued. It was treated like a living entity that needed nurturing and nourishment. Organic methods of farming were used that naturally let crop biodiversity flourish and kept the soil healthy.

Around 40 years ago, the Indian government propagated the use of high yielding varieties (HYV) of crops by doling them out at subsidised rates. These varieties needed chemical fertilizers and slowly changed the entire system of farming that originally existed. Initially people were surprised by the substantial increase in productivity, but over a period of time they realised that the yield stagnated or reduced with every year while the need for expensive and harmful chemical fertilizers and pesticides increased. The people of Jardhar decided to revert back to their traditional practices of farming. The main method they used was the *Baranaja* system where a variety of crops and plants are grown together in what seems to be an incoherent and random melee, but the system is a time-tested method of growing a variety of crops, providing a variety of needs, as also allowing biodiversity to flourish and keeping the soil healthy and productive.

The *Beej Bachao Andolan* (Save the Seeds Movement) was later started in the village to work towards recovering seeds that were lost due to the heavy influx of HYV (high-yielding variety) seeds during the Green Revolution. Since the starting of the *Beej Bachao Andolan*, hundreds of varieties of seeds have been recovered. There are a number of *Mahila Mandals* (women groups) that look into farming and biodiversity issues.

While protecting agro-biodiversity, the village simultaneously put systems in place to protect its forests. This has resulted in healthy forests and land, an increase in biodiversity and high underground water tables. This is essential for places like Jardhar where a vast majority of the population is still directly dependent on agriculture and forest produce. The *Beej Bachao Andolan* also focuses on information dissemination on conservation.

The major problems faced by Jardhar are the waning interest of the younger generation in the movement and the threats from destructive development projects like mining. Currently, the village is also trying to stop hybrids and genetically modified (GM) crops from entering their farming systems. They are fearful that the government will propagate GM seeds by selling them at subsidised rates and advertising them as the strongest and highest yielding varieties of seeds,

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much like they did with HYV seeds. The people of Jardhar think that since Uttarakhand is supposed to be an organic state, GM seeds should not be propagated.

Siddappa Setty of the Bangalore-based NGO Ashoka Trust for Research in Ecology and Environment (ATREE), talked about the agricultural and wildlife conservation practices of the Soligas, a tribe in the Biligiri Rangaswamy Temple Wildlife Sanctuary (BRTWLS). The Soligas farm on land and collect non-timber forest produce (NTFP) from within and outside the sanctuary. Prior to 1972 (the year the Wildlife Act was promulgated), wild animals consumed half of the crops that were cultivated by the tribe, which they tolerated, but later as their access to land reduced dramatically due to conservation policies, they could not afford to lose such vast quantities of crops anymore.

Traditional methods of farming are still used to grow a variety of crops and conserve seeds. They previously used shifting cultivation, leaving land fallow for four to five years to let it regenerate before using it again. This method was later prohibited within the BRTWLS, and broadcast sowing methods in settled agriculture were adopted. However, the irregular crop arrangement makes it difficult to remove weeds. To tackle this problem, the sowing patterns were changed from broadcast to in-line. The systematic rows of crop made it easier to locate and remove weeds. However, different problems cropped up with this method and it was discontinued. Farmers on hill slopes and those who did not have cattle to help them cultivate, found this method cumbersome and were the first people to revert to their earlier methods. Farmers also realised that removing the weeds gave wild boars better access to the crops. After four years of experimenting, most of the farmers have returned to broadcast farming. Traditional farming is currently threatened both by the increase in the number of coffee plantations in the area as well as the excessive growth of Lantana in the WLS, which in turn is forcing wild animals to enter the Soliga farms in search of food.

Raman Sukumar of CES and IISc, spoke about human-elephant conflict in agricultural landscapes. According to Sukumar, this is an age-old problem and cannot be completely eradicated, however, one can definitely work towards reducing losses. There should be extensive studies on the extent of damage caused by elephants along with the variety and quantity of food available in the forest, as this information will help unravel the motivational factors behind the instances of crop raiding. After all, elephants take to fields for the same reasons that humans do – limited access to forest produce, and for the nutrition and the taste of farm grown crops.

These studies can be followed by bringing about changes in cropping patterns and enforcing landscape planning to increase the availability of nutritious food for the elephant populations within forests. However, increasing forest cover does not necessarily reduce human-elephant conflict because degraded land often has a higher carrying capacity of elephants than a rich forest. Often more elephants are found in buffer zones than in core areas. This is apparent in Joint Forest Management sites where forests have provided shelter but not food for elephants. Thus, they raid crop from farms nearby and then use the newly regenerated forests to hide. Sukumar also noted that elephants are now travelling to forests where they were not found earlier. He said that although the number of conflicts has reduced over the last 20 years because the male population has decreased, the compassion people had for the animal has also decreased. Thus, communities that traditionally refused to kill elephants even when there were human casualties, are now open to culling animals to prevent farm raids.

Discussion

The presentations were followed by a discussion. One of the main questions revolved around what individuals could do to support these efforts. Jardhari asked people to revaluate their own lifestyles and find out where they could make changes. He suggested small things like terrace gardens, buying locally grown food and organic food if it was possible. He also asked people to reconsider eating industrial meat because the production and transportation of such meat costs a lot in terms of resource consumption.

Some participants questioned the viability of organic farming by stating that it was replaced by Green Revolution in the 1970s because organic farming was incapable of producing sufficient quantities to feed the country. They pointed out that food needs are much higher than they were before and will double or triple in the next few decades and wondered how organic farming would be sustainable now if it wasn't earlier. They asked if perhaps, it was necessary to continue with non-organic methods of farming and add to them by using genetically modified (GM) seeds.

The speakers reminded the audience that the Green Revolution was aggressively pushed onto farmers by heavily subsidising the cost of HYV seeds and fertilisers. However, these prices changed, the quality of the soil decreased and ultimately the production levels dropped, making this form of farming unsustainable. Furthermore, it has led to farmer suicides across the country and these deaths must be accounted for while assessing the sustainability of non-organic methods of farming.

The speakers acknowledged that organic farming also had its drawbacks and said it should be used only when it seemed to be the most sustainable (in terms of economics

and ecology) option. Unfortunately, several farmers have forgotten traditional methods of farming because they have been using the Green Revolution methods for decades. This meant that even though farmers might want to revert back to organic farming they no longer have the means and knowledge to do so.

The speakers feared that pushing GM seeds would have effects similar to that of the Green Revolution. The solution to this was forming networks that could help each other with farming methods and seeds. Linking markets and locally produced food was also the need of the hour. This has been achieved by the Deccan Development Society in Zaheerabad (Andhra Pradesh, India), by linking the public distribution system to a variety of local, organically produced, nutritious crops.

In response to the question about the looming food crisis, the speakers said the solution was not more intensive farming on larger patches of land but farming more essential foodstuffs rather than non-essential cash crops. They also recommended adopting eating habits that are easier to sustain like eating more bajra and unpolished rice. Finally, one would also have to question the social hierarchy of farming methods. For instance, dry land farming is viewed as inferior to water intensive irrigated methods even if it is more effective under certain conditions. If such false hierarchies were done away with, appropriate methods would be adopted to suit particular land types and farming would be more effective. Working on these structures takes time and energy. In Zaheerabad, it took fifteen years to prove that dry land farming was the more effective method.

The session ended with a discussion on GM seeds. A comparison was drawn between growing monocultures of GM seeds and using traditional organic forms of agro-biodiversity. People argued that if a farm has a rich diversity of crops, this diversity acts as a buffer. If a particular crop gets infected and dies, there will still be other crops that assure the farmer of some food and sustenance. This was not the case with monocultures of hybrid, HYV, or GM crops as the produce of a whole farm would be wiped out if an infection or a disease attacked the crop. The discussion veered to the ethical arguments for and against GM, and naturally available seeds. People were divided on whether they were more comfortable with one or the other kind of seeds. Participants agreed that there was insufficient scientific data to prove whether one form of farming was better than the other due to a paucity of examples of direct comparisons between the two forms. However, observations from the various examples of organic, sustainable, biodiverse farming suggested that such alternatives could be viable in the long run for India, and provide appropriate resolutions for the conflicts between agriculture and biodiversity conservation.

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COMMUNITY-BASED CONSERVATION

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Ashish Kothari of Kalpavriksh, Pune, gave an overview of community-based conservation in India. He specified three areas that needed to be focused on, namely community conserved areas (CCAs), protected areas (PAs) and landscapes outside CCAs and PAs.

CCAs can be roughly defined as natural and modified ecosystems that contain significant biodiversity values, ecological services and cultural values that are voluntarily conserved by indigenous/mobile/local communities through customary laws or other effective means. In most cases these areas have been beneficial for the local ecosystem, the biodiversity, the people and the adjoining areas.

Internationally, several policies have been formed to acknowledge CCAs, like the Convention on Biological Diversity, which has been ratified by India. There are also several Indian laws and policies that could back CCAs or co-managed (CM) areas. The National Wildlife Action Plan talks about CCAs and CMs; Wildlife Protection Act (amended in 2002) brought in concepts like Community Reserves and Conservation Reserves; The Scheduled Tribes and Other Traditional Forest Dwellers (Recognition of Forest Rights) Act, 2006, mentions community forests; the Indian Forests Act, 1927, mentions village forests. However, challenges still exist in the form of appropriate implementation of these laws and policies. Furthermore, destructive development projects and globalisation have led to the watering down of these laws and policies.

While acknowledging the importance of PAs to protect certain species and ecosystems, one must realise that over 3 million people live inside them and the creation of such PAs has led to the displacement and disempowerment of these individuals. This has caused several problems like loss of traditional forms of conservation, clashes with the forest department, illegal poaching and timber extraction, to name a few. This often negatively affects conservation itself, and defeats the purpose for which PAs were created, apart from creating enormous human suffering. But there are some initial changes taking place, such as Periyar Tiger Reserve where officials were working with local adivasi communities to enhance their livelihoods and involve them in protection. In this case too, developments in international policies such as the CBD Programme of Work on Protected Areas, which emphasised collaborative management and the integration of conservation with livelihoods, could lead to more equitable conservation within India.

The landscape approach seeks to connect different areas under conservation and sustainable use, and form extensive stretches of conserved areas rather than little islands of protection. This could include CCAs, PAs and many other forms of conservation sites to form a strong mosaic of conservation.

The overview emphasised the need for participatory methods of conservation that ensured wildlife protection and the rights of local people to life and livelihood.

Kanhaiya Gujjar, a villager from Bhaonta-Kolyala villages working with the NGO Tarun Bharat Sangh in Rajasthan, spoke on community-based landscape conservation in Rajasthan with reference to the River Arvari in Alwar district in Rajasthan. The area had thick forests, but lost them during colonial rule. This trend continued after India became an independent nation and caused many problems like the drying up of the Arvari, severe droughts during dry seasons and excessive soil erosion during the monsoons. In 1987, along with the Tarun Bharat Sangh (TBS), the villagers conducted a meeting to address various local problems. They decided to regenerate their forest and revert to traditional forms of water management to restore the ecological balance of the area. To achieve this, rules about forest use were implemented and traditional water harvesting structures (*johads*) were constructed. Their efforts paid off when the river regenerated and started flowing again. Currently, there are 30 tanks in the area as opposed to the 4 that existed when the movement started.

Several threats have cropped up since the revival of the river. One of the main problems was the fishing contracts leased out by the government to private bodies. The TBS opposed this and won the struggle. They realised the need for their own governing body that would protect the river from such instances in the future. They formed the Arvari Sansad (Parliament). This is the first peoples' parliament in the country. It has 242 elected members and various internal communities that look into matters related to the river (including water sharing, wildlife and forest conservation, inter-village disputes, and others). However, they still face

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various challenges including boundary issues with their neighbours, threats of mining and other development projects, election politics that threatens to fragment their society and insufficient cooperation from government bodies.

Tsilie Sakhrie, an Angami tribal from the Khonoma Tragopan Sanctuary Trust in Nagaland, spoke about community conservation of the Blyth's Tragopan. Khonoma is a village in Kohima district, Nagaland, that is rich in biodiversity and home to the threatened Blyth's Tragopan. Sakhrie and a few others set out to protect this bird and conducted various conservation activities. Since, hunting was traditionally acceptable and glorified in Khonoma, they initially faced a lot of resistance and opposition to their conservation efforts. Through continuous interactions with the community, Sakhrie and his colleagues made people realise the importance of conserving the Blyth's Tragopan and the village moved away from hunting and towards conservation. In 1998, the Khonoma Nature Conservation and Tragopan Sanctuary was officially established. It is managed and supported by the local community.

Vijay Jardhari, a farmer, spoke about community conservation in his village Jardhargaon in Uttarakhand. This village is situated in the Himalayan foothills at an altitude of 1,500 metres. It has 17 settlements with 8-10 families each. The major occupations here are agriculture and animal husbandry. They rely on local forests for firewood, fruits, fuel and medicinal plants. By 1980, deforestation activities conducted by the forest department and local people had left the forests almost bare. Jardhari was a part of the Chipko movement and was aware of the power of peoples' movements. In 1980, the people of Jardhar had a meeting and decided to work towards regenerating their forests. They formulated rules and appointed guards to protect the forests. They formed a *Van Suraksha Samiti* (VSS) or Forest Protection Committee, and appointed a forest guard with their own resources. Within three years, the forest had regenerated substantially; within 30 years it had become dense with high biodiversity.

Having dealt with their forests the villagers also decided to stabilise their farming methods. Chemical fertilisers had affected farming in the area so they reverted to traditional forms of farming. They collected and distributed local seeds and started the *Beej Bachao Andolan* (Save the Seeds Movement). Despite their success they face several problems. There has been a significant increase in human-wildlife conflicts, the community natural resource management enjoys no legal backing, and government policies that promote chemical intensive farming methods are in direct conflict with their traditional methods of farming.

Anil Bhardwaj of Wildlife Institute of India, Dehradun, talked about the ecodevelopment project in Periyar as an example of successful local community involvement in a tiger reserve. In the 1980s and 1990s, Periyar was viewed as a rich forest, but was actually riddled with problems ranging from ganja cultivation and poaching to waste problems caused by tourists and pilgrims. The roots of these problems lay in poor park management and heavy dependence of local people on the forest. Thus, it was decided to pilot an eco-development project to meet the needs of conservation and livelihood. Local people would be involved in protecting the PA and alternate forms of livelihood would be made available for them to offset the losses accrued by changing their traditional methods of using the forests. The project also envisioned converting poachers into protectors, forming women groups and local self-help groups to create a strong base of local people who would support the project with their knowledge of the forest and learn new skills to propel the project further. They worked towards creating several eco-development committees that handled different issues, helped local people get rid of their debts and arranged for them to be involved in conservation and documentation work. Local communities are trained to conduct eco-awareness camps and are part of regularising the pilgrims in the park. Through a slow process that began with creating a relationship based on trust between the local people and forest officials, a working model of joint conservation has been created.

Charudutt Mishra of Nature Conservation Foundation and the Snow Leopard Trust spoke on community-based management of human-wildlife conflict, with special reference to the work going on in Spiti, Ladakh. He spoke about two basic dimensions of the effort – understanding the conflict in the area, and managing it. While undertaking the first part, one must take stock of the situation and understand the perceptions and psyche of the people in the area apart from the actual information on losses. These are extremely important when it comes to actually implementing the management plans. In Spiti, Snow Leopards were highly dependent on livestock in some areas and were responsible for *c.* 12% of the livestock losses. The perceptions of the damage caused by the animal were magnified because of a lack of data (actual losses, causes, circumstances of loss) and because of insufficient and delayed compensation for livestock losses. The best way to deal with human-wildlife conflict, was to address all three of these simultaneously – reducing livestock losses, economic offsetting and increasing the social understanding of the situation. In Spiti, they reduced livestock losses by putting better herding methods in place, and increasing the populations of wild prey of the Snow Leopard. They created community-based insurance which is run by the community and gives complete compensation much faster than the government bodies because of simpler

verification and disbursal procedures (uncovering false claims is easy in a small community). Conducting educational programmes and giving incentives to undertake conservation have increased social understanding. This programme has been running successfully for over five years and livestock losses have reduced dramatically. Mishra pointed out that while it was important to have community-based management plans, there should also be governmental support.

Panel discussion

Madhu Ramnath, an ethnobotanist, talked about the importance of lesser known non-timber forest produce (NTFP). He said that while the most prominently discussed forms of NTFP tend to be profitable ones like Tendu patta (*Diospyros melanoxylon*), sal seeds (*Shorea robusta*) and Mahua (*Madhuca indica*), there exists a rich diversity of non-commercial NTFP that are vital for the health and subsistence of local communities.

The commercially viable forms are used to make a variety of products from cigarettes to alcohol. The collection processes are often highly politicised, involving power struggles between local communities, forest departments, local governments and private bodies. The other forms of NTFP exist in the form of fibres, leaves, poisons, berries, yams, etc. with specialised functions related to health and survival.

With 20% of our population still directly dependent on such produce, one should not undermine the power of these forms of NTFP. Ramnath stated that although commercial NTFP assured local communities some money, the non-commercial ones were far more important because they could ensure good health, food security and sovereignty. They also required and could ensure the maintenance of healthy, biologically diverse forests.

Sharad Lele from the Institute of Social and Economic Change in Bengaluru, spoke on forest-based enterprise and community-based conservation. He enumerated the barriers that impeded the two from interacting effectively. The attitude of those in power is the biggest barrier that prevents local communities from taking part in conservation activities. He pointed out that in all the case studies discussed in the seminar, local communities had to prove their worth as conservationists to external bodies before they were allowed to partake in the process of conservation. Often, when the local communities are involved in conservation processes, they are given menial tasks or ones with lower levels of responsibility. This is indicative of the level of trust extended by external bodies to the community. The right of local people to be intricately involved with wildlife conservation and eco-tourism in their own area should be acknowledged. Ultimately, instrumental approaches to CBC have been used rather than focusing on rights-based approaches. Another problem was the paucity of formal spaces where local communities could legally partake in conservation efforts. This could change with the implementation of the Forests Rights Act because it has potential to acknowledge these rights. Lele also reminded external bodies that it is alright if the fiscal profits expected by local communities from eco-tourism and other profit generating enterprises are lower than what the external bodies expect.

Tushar Dash from Vasundhara in Orissa, spoke about community conservation and the Forest Rights Act. Orissa is a state with 62 tribes where 13 primitive tribal groups are mostly forest dwellers, 44% of the land is scheduled area and over 40% of the people are critically poor and dependent on the forest for livelihood. Thus, it is important to recognise the rights of local people, whose lives have been and continue to be, intricately linked with the forest, while looking into conservation issues. He talked about two forms of conservation: the exclusive approach and the community conservation initiatives (CCI) approach. The former works towards creating conservation enclaves and normally ignores or denies traditional practices, the rights of local people to be involved in conservation processes and their rights to livelihood. The latter is normally based on traditional knowledge and practices that have developed over time and addresses the issues of rights and livelihoods. Traditional forms of CCIs are present all over Orissa. Currently, there are about 12,000 forest protection groups working around two million hectares of forest rich in biodiversity. This includes initiatives in wetlands and coastal areas, and species protection and conservation based on cultural or spiritual beliefs.

These initiatives require legal backing, recognition of rights and protection from development threats. The Forest Rights Act (FRA) has, to some extent, achieved these goals. It has been used in places like Nayagarh where 200 villages have claimed rights over community forests that they have been protecting. In Niyamgiri, the Dongria Kondhs have used FRA to fight a mining project that threatens the area. Section 5 of the Act gives *Gram Sabhas* the right to form conservation and development committees, and Community Biodiversity Management Plans have also been used to increase local participation in conservation processes. Thus, the FRA has the potential to ensure greater involvement of local people in conservation efforts. But the main challenge lies in making more people aware of the act and in implementing it.

Nitin Rai of Ashoka Trust for Research in Ecology and Environment (ATREE), Bengaluru, talked about community conservation in Biligiri Rangaswamy Temple Wildlife Sanctuary of Karnataka. There exist, within the sanctuary, several sacred sites of a tribe called the Soligas.

Most of these sites have not been identified on modern maps. There are five tribes with a total population of 12,000 who live in and around the sanctuary. They have created a cultural map, where 593 sacred spots have been denoted. The Soligas also defined various vegetative classes that were highly specialised, based on information like the contour of slopes, the composition of the area, the density of flora and several other similar pieces of information. This map, with its different vegetative classifications and cultural sites, is a historical and cultural map of the Soligas. They see it as a method of supporting their right to claiming the forest and argue that they can claim the land because they have used the same method employed by urban people to claim land – which is, naming and mapping areas. There are various efforts towards claiming these rights through Section 33b of the Wild Life Protection Act (2003 amendment) and Section 5 of the Forest Rights Act.

General discussion

After the presentations and panel discussion, there was a question-answer session and a discussion. The discussion revolved around the problems of CBC. This included the fallouts, loopholes and unforeseen complications of this method of conservation.

One common problem in most of the successful sites was an increase in human-wildlife conflicts, especially with monkeys, wild boar and nilgai. The discussion brought out a variety of possible solutions ranging from culling and hunting to changing cropping patterns. However, the group acknowledged the difficulties in implementing these methods due to religious/cultural values attributed to the animal in question and due to ethical doubts about the right to cull animals. Other solutions were urgently needed.

Conflicts between generations based on changing values and materialistic desires are also common to these communities. Younger generations often do not wish to actively continue with the traditional paths that the previous generations have created. This problem becomes acute when destructive development projects, that claim to offer employment and salaries, are proposed in these areas. While the youth focus on the money that could be earned through these projects, the older generations focus on the changes in the ecological conditions of the area and social fabric of the community. Kanhaya Gujjar shared his experiences with the group where families did not speak to each other because they differed over a mining project that was coming up in their area. However, when the youth saw the rapid changes in the society that took place because of the influx of foreigners, they realised that the social cost outweighed the monetary benefits and they too fought against the mining project.

Some people wanted more scientific data to prove the effectiveness of CBC. A need for scientists and researchers to conduct studies on the feasibility of these initiatives was identified. These studies could determine factors that have helped or impeded the CBC site and subsequently help with future endeavours.

Part of the discussion revolved around what urban people could do to contribute to CBC initiatives. One method was supporting similar activities in their own areas. An appeal was made to support laws and policies that helped CBC. The FRA was taken as an example of a law that could give people the rights they have long been denied. However, there has been misguided opposition to this act, and lawsuits aimed at nullifying the act because it is viewed as a threat to conservation. Rather than removing the act, people could work towards improving it through amendments and through its implementation, and ensuring that it aids conservation processes.

An important point from the talks that was repeated in the discussion was that the CBC may not work for all ecosystems and people. It is not a panacea for all situations, but one in a larger mosaic of conservation methods.

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